The Institute of Physics

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The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

South Western Branch

Following a formal request from members in accordance with By Law 38, the Board has approved the formation of a South-Western Branch of the Institute to be centred on Bristol. The inaugural meeting takes place on Monday, May 13 (*see page 161*). Professor S. H. Piper (*Fellow*) and Dr. S. H. Ayliffe (*Associate*) are acting as Chairman and Honorary Secretary respectively until the inaugural business meeting.

Graduateship Examination

Because of the large number of candidates, the Graduateship examination cannot this year be held at the Institute's House ; candidates taking written papers in London will do so at The Polytechnic, Regent Street.

Oxford Convention

There is still a limited amount of accommodation available for members wishing to attend the Institute's convention at Oxford from July 10 to 13. Forms of application should be returned as soon as possible.

Radiofrequency Spectroscopy Symposium

Members are reminded of the Symposium to be held on September 19 to 21 at the University of Southampton, dealing mainly with electron resonance techniques. Details may be obtained from the Deputy Secretary.

Postgraduate Education*

By Professor N. F. MOTT, M.A., D.Sc., F.Inst.P., F.R.S.

(*Cavendish Professor of Experimental Physics, University of Cambridge*)

WHEN The Institute of Physics asked me to talk to the Education Group, I chose as my subject " Postgraduate Education " because in the Cavendish Laboratory we have had some discussion about the proper balance between formal teaching and research in this part of a man's career. But postgraduate teaching is just a part of the whole problem of scientific teaching. Therefore I would like to review the whole subject as it affects the teaching of physics in the University of Cambridge, with special reference to our postgraduate education and research.

The essential problem before us is this : when are our students ready to start research in the university, or when are they ready to leave the university to start research in industry or to teach in schools. Our usual answer in England is that after two or three years of specialization at school, and a three years' undergraduate course, they are ready. We recognize that this training is less than is usual in America or on the Continent, but, if we justify it, we do so on the grounds that our school education in the sixth form takes boys further in science than that in other countries, and also on the grounds that it works.

Now before talking about postgraduate teaching and the kind of instruction that may be desirable after the three year undergraduate course, let me say a few words about school teaching and see whether there is likely to be any tendency for boys and girls to come up to the university less well prepared than at present ; whether or not this is expected may obviously affect our views on the length of university course likely to be desirable.

I think that there is reason to suppose that there is such a tendency. Each year more boys and girls in the schools want to do science, but the number of capable science teachers does not increase in proportion. Apart from this there is a strong feeling among many educationalists that we would be wise to diminish the pressure in the sixth form and to include more time devoted to the humanities ; results of either policy would be to diminish the amount of science that a boy is able to learn. I myself believe that it is important to defer as long as possible the choice whether to do science or something else, at least to sixteen years old or later. I think that it is up to us in the universities to provide, through our entrance requirements and scholarships, the incentives for the schools to educate their boys in such a way as to defer the choice and to broaden somewhat the sixth form education, and there is much discussion going on as to how this should be done and, I believe, much sympathy in industry for the attempt.

If, either through deliberate policy or through lack of good enough teachers, some boys and girls come up to the universities less well prepared than at present to reach the present standard of the honours degree, we shall have to keep them longer. I do not think that many universities will want to extend the present three year undergraduate course to four years, especially at a moment when we have to look after the bulge in the population. Particularly at Oxford and Cambridge, where any great extension of the residential facilities is hardly possible, an extension of the undergraduate course from three to four years would merely mean that fewer men and women would benefit from whatever unique educational advantage residence in a college is believed to give. But none the less I think the universities will have to do some-

* Based on a lecture given to the Education Group of the Institute on December 13, 1956

thing extra both for their less gifted students—or at any rate for those who are less well prepared—and for their most gifted who need more specialized information than they at present get.

Turning first to the problem of the less well prepared, I think we must anticipate a revival of " Intermediate " courses and hope that local authorities will encourage boys to take them. As you know, Imperial Chemical Industries Limited are awarding bursaries for boys who have done arts subjects at school and want to change to science, bursaries which enable them to spend an extra year at the university for the purpose. Oxford, Cambridge, Imperial College, Liverpool and King's College, Durham, have arranged special courses for these students. I hope the movement will grow ; that at a sufficient number of schools the arts sixth will not drop mathematics and science so completely as at present so that these candidates will not be faced with so formidable a task as they are now, and that then arts at school followed by science at the university may be a course which many choose to take, not only those who change their minds. I hope that a student will not have to do his preliminary year at the same university as he does his proper course. At present it seems uneconomic to set up such courses in too many centres. As long as Oxford and Cambridge work within the framework of three eight week teaching terms it is doubtful if they are the best places for a young man to undertake the tough job of learning all of sixth-form science in one year.

Now let us turn to the undergraduate course itself, the normal three years' honours course. This aims to bring a student to the point where he has some knowledge of modern physics and perhaps in just one corner can stand at the frontier of knowledge —or at any rate hear a lecture or two on unsolved problems in some branch of physics. The extent to which the course attempts to introduce him to other sciences varies greatly, Cambridge with its Part I going further than most, a policy which has the compensating disadvantage that the advanced work, the Part II, is very rushed. But after this three year course students normally start research for the Ph.D., or take jobs in industry or government service, or (perhaps after a further year in an education department) start a career in teaching.

Let me consider first the people who are going into industry without taking a Ph.D. We have to ask, do they know enough ? Is there anything more that the university can give them, and ought to give them ? I think there is. I think many university physics departments are capable of giving a specialized postgraduate course lasting a year, based to some extent on the kind of research they do, which would be of real value to men entering industry and provide a training which industry normally cannot give. For instance one could envisage a course on neutron physics for the future nuclear engineer provided by a university which specialized in nuclear physics, a course in solid state and band theory for the future worker on semiconductors, or on dislocations for the future physical metallurgist. Of course, some postgraduate courses do exist already ; my impression is that many of them are used mainly by overseas students, and that graduates of our universities have no difficulty in finding the kind of jobs that they want immediately after their degree and without attending such a course. If courses of this kind would be valuable, employers in industry and government service might send their recruits to one after engaging them. After all, a student will rarely know *which* of several courses offered he ought to take until he knows where he is going for his first job. And without definite encouragement from industry, will he wish to spend another year supported by a grant from the Department of Scientific and Industrial Research relatively meagre compared to what he could earn in a job ?

The staffing of such postgraduate courses may be a problem. I think that the universities might explore the possibility of borrowing men from nearby industrial and government establishments and research associations rather than seek to increase their staff too much for the purpose. Universities

owe much of their health and vitality in scientific subjects to the fact that they combine teaching and research, so that a university teacher can spend a part of his life in which the one is his main preoccupation, another part of his life with the other. We are now building up colleges of technology in which a man will make his career in teaching, research associations and many other organizations in which a man will make it in research. It is a pity that the two should be separate. Anything the universities can do, drawing from their own happy experience, to break down the barrier, would be valuable.

But much of the teaching necessary for such courses may well have to be provided anyhow for the students who stay for the Ph.D. Compared with the Americans, our university students get relatively little formal instruction, and there has been a good deal of discussion in the physics departments of British universities about how much, if at all, we should imitate their system. One good feature of our Ph.D. course is that after the B.A. or B.Sc. examination a student makes a break with being taught through attendance at lectures, and thereafter has to teach himself from books and from a sometimes rather haphazard selection of postgraduate lectures. Some experienced directors of research in universities think this sudden break is educationally valuable, compared with the gradual transition from formal teaching to research usual in America. While admitting this others feel that the British postgraduate student really does not learn enough and that his reading tends all too often to be narrowly centred round his research problem. Two criticisms in particular have been made ; one is that, especially in nuclear and solid state physics, he does not acquire the same familiarity with quantum mechanics as does the American student, or the ability to use it for the simpler kind of problem. Where is the English university which gives its students anything like the eighty-four lectures in quantum mechanics which Bethe hands out at Cornell ? I have heard this thorough teaching of theoretical and nuclear physics in America described as producing " meson engineers "—but why not ? If there is anything which observation of the American system demonstrates, it is the capacity of thorough teaching to produce good research workers from men who would here get a 2(ii). This is worth doing ; and indeed we do not look down our noses at a man with a " good " 2(ii) for research in the Cavendish Laboratory.

The other criticism of too sharp a break after the first degree is this : if a man is going to do research for a Ph.D., it is then that he has to decide on his subject. But one fears that often he does not know enough to do this. So many of the most fruitful fields for a physicist in the next decade are clearly going to be in the borderlines between physics and biology, or between physics, chemistry, metallurgy and engineering. It would be a great advantage if some enterprising students could spare a year, before settling down with a supervisor and a research problem, to have a look at one of these other disciplines. The new arrangements for postgraduate training grants made by the D.S.I.R.* will make it much easier to move from one university to another ; only with some more time, I believe, will they know how to make the best use of this flexibility.

All this adds up to a demand for four years for the Ph.D. in physics—not for all students by any means, but for quite a number including some of the best, and particularly for those who have enterprise to step outside the fashionable main stream of the moment into a new or borderline subject I would not say this unless I had a profound belief in the value of a course of research in a good school—not of course for the magic letters after your name or for the bit of scarlet on your gown, but as an experience which brings a man fully into the world of national and international science and which teaches him to stand on his own feet. A Ph.D. course is not the right training for everyone ; but no one who has seen young men of talent develop under it can doubt its extreme value for some.

Also it is through the work of Ph.D. students and of the much smaller number

*Notes on D.S.I.R. Grants revised January 1957.

of post-doctoral workers guided by an experienced teacher that advances in fundamental science are made, as often as not. Nobody will doubt the value of the university groups that since the war have opened up new fields of knowledge, such as those of Powell or Ryle or Bleaney, to mention only a few. No one would doubt that research students should come to such groups; men want to come and work in them, and my only plea is that they should have more time and be free to learn a little more—and indeed urged to do so, and restrained for a few more months from the exciting and compelling job of advancing knowledge. Given this, nothing could be better training.

The outstanding groups present no problem and deserve—and I am glad to say usually manage to get—every support. But I think to conclude this lecture there is something that I can usefully say about the smaller groups that one finds scattered up and down the country working on solid state or magnetism or low temperatures or something else. Contrasting the situation with that in American universities, and still more with fundamental research in American industry, research in this country is too fragmented; the individual groups are too small. The advantages of size in research are very great; the stimulus of having workers in related subjects at hand is of great importance and in my experience men of second class ability will in such an atmosphere do work of the calibre of first class men elsewhere. And, if it is the question of the application of research, in a big group it can be seen which advance in fundamental knowledge should be taken up and applied.

Here I believe the organizations that represent physics in this country have an important part to play. Research units here, in universities, in industry and government, are bound to be smaller—with a few exceptions—than in the United States. The groups and meetings organized by the Institute, The Physical Society, The Royal Society and other bodies play an important part in keeping the workers in a given field in touch with each other. But I wonder if they could not do more. Is it too much to hope that the effort in this country in a given field could operate in some sense as one group, with frequent meetings and—by mutual consent—some deliberate planning and co-operation? In this way I feel that we would have more success in making certain fields our own, in clearing them up and, on the applied side, in getting something out of them. And, if I may finish on the theme on which I began, postgraduate education, what better training can one imagine for a young man than to be introduced to the physics of the whole country in this way?

The Inaugural Meeting
of the Institute's
SOUTH-WESTERN BRANCH
will be held on
MONDAY, MAY 13, at 8 p.m.
in the
H. H. Wills Physics Laboratory, University of Bristol
Professor H. S. W. MASSEY, F.R.S.
will lecture on
"The Study of the Upper Atmosphere using rockets and satellites"

Reviews of Books

THE DRAMATIC UNIVERSE VOLUME I : THE FOUNDATIONS OF NATURAL PHILOSOPHY

By J. G. Bennett

London : Hodder & Stoughton Ltd. Pp. 534 + lii. Price 42s.

Scientific knowledge in all fields is growing at an accelerated pace and this has created many problems. In the absence of a sound overall picture of man and his place in the scheme of things, the powers conferred by modern technology constantly threaten to outstrip the ability to use them wisely. This is a philosophical problem—if not a religious one—and both philosophy and religion are faced with a curious dilemma, the like of which does not appear to have arisen at any time in the past. Only a few specialists in each field have a reliable grasp of the detailed facts ; but it is the sum total of all the facts that must be taken into account in philosophical discussions ; and no one thinker is capable of knowing a thousandth part of what is required. The inability of non-specialists to use scientific concepts is well illustrated in a series of articles now appearing in the *Sunday Times* on the perennial question of life after death, where only in Bertrand Russell's rationalist philosophy does science play any part. Examination of Russell's thesis discloses two of the reasons for this situation. First, Russell states that " the physical world, as physicists conceive it, no longer consists of *things*, but of *events*." This ignores the modern scientific tendency to be content to describe observational data rather than search for an understanding of phenomena. Things, as such, disappear in general relativity when the framework property of a curvature tensor is substituted for matter. The successful use of wave functions, supplemented by selection rules, seems to have diverted attention from the baffling nature of the wave-equation. Second, Russell compares his physical world with Hume's famous passage on the perpetual perishing of personal identity and is led to ascribe the continuity of a person to memory. Here the reader needs some account of how memory (or the brain) can be organized and yet be subject to the second law of thermodynamics. In *What is Life* Schroedinger recognized this problem when he spoke of " living organisms sucking negative entropy out of their environment." In *The Dramatic Universe*, J. G. Bennett goes further and offers a unified treatment of the twin problems of organization and differentiation that is a major contribution to our understanding of the meaning of the knowledge now available in the various scientific disciplines.

In the first twelve chapters Bennett constructs a *schema* for all knowledge. These chapters, ranging over a wide field of philosophical speculation from pre-Greek to Whitehead, are difficult. Serious study is aided by the extended table of contents and a glossary of special terms. Twelve grades of existence are postulated, these falling into three groups corresponding respectively to the physical, animate and cosmic orders, with active colloidal surfaces and the biosphere as two transitional grades. The undifferentiated ground state, thinghood and individuals each have their place on this scale. The systematics is coherent and comprehensive.

Bennett distinguishes carefully between existence and framework, defining the latter as the determining conditions of what is possible. In an earlier publication (*Proc. Roy. Soc., A*, **198,** 39), he abandoned curved space - time and, following on from Minkowski's flat world, proposed an ampler framework in which acceleration was treated as a displacement in eternity. Throughout his book he uses a six-dimensional framework : space, time, eternity and hyparxis. For eternity the laws of thermodynamics are reversed and possible organization is determined. Hyparxis, meaning ableness-to-be in Aristotle's usage, determines possible differentiation. Always there is the feeling that what is said in this bold attempt at a compact universalism has significance, coupled with

the realization that the conclusions deserve further expert elucidation.

The six chapters on physics and the six on life are not easy to review briefly and choosing one topic may serve best to illustrate the author's thesis. We find the scheme :

	Time	*Eternity*	*Hyparxis*
Bipotent corpuscles	neutrino	electron / positron	photon
Tripotent particles	neutron	proton / anti-proton	nucleon

The existential distinction of double and triple potency between corpuscles and particles is illuminating—indeed illumination can be said to be the outstanding characteristic of the book taken as a whole—and it will be interesting to see what theoretical physicists make of this conception. But whereas the discussion of the three corpuscular states is rewarding, the consequences of regarding the nucleon as an hyparchic state of a single ultimate particle are not developed at all. Although it is perhaps unfair to expect more in a treatment of the whole of science in 500 pages, such incompleteness is a troublesome feature of the book.

Aspects of personal freedom that naïve thought would regard as belonging to the realm of value judgments are given an uncompromising factual explanation, so the second volume should have especial interest in understanding our human situation.

R. L. Brown.

RAYONNEMENTS DE PARTICULES ATOMIQUES, ELECTRONS ET PHOTONS

By André Berthelot

Paris : Masson et Cie. Pp. 191. Price 1,800 fr.

This book has no close equivalent in English. It does not attempt any extended theoretical treatment of the features considered, but gives the results, with a selection of references, in a form readily applicable in normal experimental conditions ; there are well-chosen examples of numerical data. When this has been said, it remains doubtful if it can be really helpful to most experimental workers, for the detail of treatment will be found inadequate over those fields in which any worker has active interest, and the lists of references are hardly complete enough to make a useful guide. On the other hand, a consequence of the very limited theoretical exposition is that the reader finds little indication as to the relative importance of the various topics, a difficulty in the way of the general reader wishing to survey the properties of energetic particles moving in matter.

After a preliminary discussion of elastic collision under typical laws of force, the main sections cover :

(i) the charge equilibrium of particles near the end of their range.
(ii) loss of energy by heavy particles, including Čerenkov emission and the density effects.
(iii) range, and fluctuation of range.
(iv) nuclear Coulomb scattering of heavy particles.
(v) loss of energy by fission particles and their range.
(vi) loss of energy by electrons ; ionization and bremsstrahlung.
(vii) scattering of electrons, and
(viii) interaction of photons with matter ; photoeffect, Compton effect and pair formation.

This in some ways rather disappointing book is attractively written and excellently illustrated.

J. G. Wilson.

DIFFERENTIAL EQUATIONS

By H. W. Reddick and D. E. Kibbey

London : Chapman & Hall Ltd. New York : John Wiley & Sons. Pp. 304 + ix. Price 36s.

This is the third edition of an American book first published in 1943. It deals mainly with ordinary differential equations and the usual methods of solution, including the method of solution in series. All this is clearly explained and well illustrated by examples, many of them taken from mechanics and physics. A final short chapter has been included in this edition on partial differential equations.

It is an excellent book on traditional lines, but one wonders whether in these

days any book on differential equations should omit any reference to numerical and graphical methods of solution.

J. TOPPING.

LECTURE NOTES ON THE USE OF THE MICROSCOPE

By R. Barer

London : Blackwell Scientific Publications. Pp. 76 + vii. Price 7s. 6d. Second Edition.

The early appearance of a second edition of this short book will confirm the suspicions entertained on its first publication, namely, that it serves excellently its purpose as an introduction to the microscope for biological and medical students. It may be added that many physicists would also profit from this book when they first have occasion to use the microscope.

The author has intentionally limited himself to a practical account of the ordinary microscope, the choice of objective and eyepiece, and, most important, the correct procedure for the adjustment of the illuminating system. For this reason no account is found of the more recently introduced techniques, such as phase-contrast and interference microscopy. Even the use of vertical illumination is omitted. Within his self-imposed limits, Dr. Barer has given an account which is marked by technical accuracy and lucidity of explanation. The first of these derives from his own extensive practical experience with microscope techniques, to which he has contributed not a little ; and the second would appear to have resulted in part from using the script of the book in experimental " runs," in which it was used by the upper forms of two schools and then by a class of medical students.

It is the duty of a reviewer to search for both the defects and the merits of a book. There appears to be only one serious statement which one might wish to qualify. This occurs on page 23, where it is stated that when an objective is claimed to have very good depth of field, it " can only mean that its N.A. is less than that of other objectives of the same magnification." Another, and perhaps more probable, explanation would be that the objective has large aberrations giving an image otherwise poor in contrast and resolution. The author is certainly well aware of this, and it may be that he is paying too much heed to the sensitiveness for which some microscope manufacturers are known. If so, we can only hope that he will be less sparing in this respect in the future.

H. H. HOPKINS.

ELASTICITY, FRACTURE AND FLOW WITH ENGINEERING AND GEOLOGICAL APPLICATIONS

By J. C. Jaeger

London : Methuen & Co. Ltd. Pp. 152 + viii. Price 10s. 6d.

This book is intended as an introduction to standard theoretical works with emphasis on the assumptions and practical applications. It develops the standard relations of stress and infinitesimal, finite homogeneous and hydrostatic strain in two and three dimensions. Biaxial systems for perfectly elastic isotropic and anisotropic solids are discussed.

The different criteria for yield and fracture are given, including a note on Griffith's theory of brittle strength. The equations of equilibrium are derived from the equations of motion and a number of special cases in elasticity, viscosity, plasticity and wave propagation are discussed.

In 150 small pages it is not possible to present more than the basic mathematics of such a large field of knowledge. Engineering students in this country would be familiar with many of the concepts given in detail before they had acquired the mathematical tools assumed by the author. The lucidity and conciseness of many chapters is admirable but the book would be greatly enhanced by a list of symbols at the front and an alphabetical list of references at the back. Reference back to section numbers is tedious if the sections are not paginated. Some of the diagrams are of little assistance in understanding the text, and Fig. 10a is inconsistent with equations 5 and 6 on p. 24.

The insufficient attention to detail does not detract from the fundamentally sound purpose of the book which is to form a bridge between different disciplines using the same concepts and theoretical basis. From this aspect the book is to be commended to physicists as presenting a geologist's approach to these problems. The scope of this book is so wide that everyone who reads it will find unfamiliar material or a new approach to a familiar subject. The second edition of this monograph should be in every scientific library.

H. FESSLER.

RADIOLOGY PHYSICS

By Professor J. K. Robertson

London : Macmillan & Co. Ltd. Pp. 330 + xvi. Price 36s. Third Edition.

This new edition of Robertson's well-known book will be welcomed by all teachers and students of radiology. Starting, as in previous editions, with the principles of a.c. circuits and their application to high tension generators, the author deals with the production of X-rays, the atomic processes underlying their absorption and scattering, and the measurement of dosage and quality of ionizing radiations generally. New developments in radiology, including image intensifiers, synchrotrons and linear accelerators are described, and a useful new section is included on radioisotope production and the physical characteristics of these substances in so far as they relate to medical work. The book has been kept approximately to its original length by omitting obsolete or unnecessary sections.

Most of the inaccuracies in previous editions have been eliminated and the book reads more easily, though it is disappointing to find so many quotations given word for word from other authors (without references) where a few words of concise explanation would have conveyed the meaning better. It is to be regretted, too, that radium therapy is given such an insignificant place in comparison with X-ray and isotope therapy when in fact it still ranks high in importance.

Cross referencing in the book is good, and there are well chosen examples at the end of each chapter.

This book may be very warmly commended to all students for the Diploma in Medical Radiology as well as to radiographers who wish to acquire a more thorough knowledge of their subject than is needed for the ordinary qualifying examination. It is without doubt one of the best books available on the subject and will be appreciated by all who seek an up to date textbook in this field.

F. T. FARMER.

AUTOMATIC PROCESS CONTROL FOR CHEMICAL ENGINEERS

By N. H. Ceaglske

London : Chapman & Hall Ltd. Pp. 228 + xiv. Price 54s.

This book is intended to give chemical engineers a mathematical introduction to automatic process control. The first two chapters describe measurement and control equipment used on chemical plants and the remaining five chapters are devoted to the derivation and solution of the equations of simple linear control systems.

The mathematical analysis, which commenceswith a brief but adequate introduction to Laplace transforms, is verywell written and easy to follow. Although the book may leave the reader with the erroneous impression that the mathematical analysis of automatically controlled chemical plants is relatively easy, the author stresses that he has only treated linear systems having a single feedback loop and lumped-constants. He points out, however, that very few chemical processes can be reduced to such simple terms.

The two chapters which describe measurement and control equipment are not so well presented. The author has made the common mistake of including, from manufacturers, literature, a large number of diagrams and photographs which are neither self explanatory nor fully explained in the text. The reader would be better served by a smaller number of diagrams specially prepared to illustrate the points under discussion.

The book is a useful contribution to the literature and can be recommended.

J. W. BROADHURST.

Degree and Diploma Courses in Applied Physics

(continued)

FINAL SESSION

Friday, November 16, at 2.30 p.m.

Chairman : E. R. DAVIES, Esq., O.B.E., F.Inst.P.

(Director of Research, Kodak Ltd., Harrow)

Dr. J. Topping, F.Inst.P.

(Principal, Acton Technical College)

I am very much aware of the difficulty, at this stage in the conference, of saying anything either novel or constructive, but I will start by commenting on the question which Professor Lipson asked at the end of his excellent address this morning, when he asked whether or not the term " applied physics " could be given to his course in Manchester. Either he was too modest or he protested too much. My answer is that if this is not applied physics I do not know what is. This is the sort of course that The Institute of Physics has had in mind when for so many years past it has been advocating courses in applied physics.

I could not help thinking that it was a complete answer to what Professor Blackett said yesterday. That is perhaps rather a strange thing to say, because I know that when Professor Lipson was developing this course at the Manchester College of Technology Professor Blackett was professor of physics in the university, and I am sure that Professor Lipson would be the first to say how sympathetic and encouraging Professor Blackett was ; but I think we had the impression from Professor Blackett's talk yesterday that he thought that there was no need for a course in applied physics. He emphasized the problem of numbers, and it is a great problem, to which I hope to return later, and said that slight modifications in the courses were unimportant. He changed that, I thought, when replying at the end of the discussion yesterday, and I think then more truly expressed his real attitude to courses in applied physics.

As Professor Gavin said this morning, we do not profess to know precisely the answer to the question " what is a course in applied physics, or whatever name you choose to give it, that we should put on in technical colleges to train the physicists who are so much needed," but I think that the work which Professor Lipson and Professor Gavin have done in Manchester and Birmingham is a very good pioneering effort, and all of us in The Institute of Physics and in education generally should be very grateful to them. There are also courses in other colleges, which will contribute vital elements to our experience in this field.

If I were to try to summarize our aims in these courses in applied physics I would say that we are attempting to do two things. First, we are helping the students to acquire a knowledge of physics and of some of the applications of physics in industry ; secondly —and I think that this is possibly more important—in so doing we are trying to help them to appreciate what is the scientific approach to a problem, how the physicist in particular and the scientist in general approaches the new and the unknown and how he expresses a scientific answer to a question. It is this second purpose which is

much more difficult to achieve. It is not something which can be enshrined in a syllabus, but I am sure that it is something which should permeate all our teaching, not only of physics but of mathematics.

I want to say a word about the teaching of mathematics and to take up something which Dr. Thomson mentioned yesterday. I am in general agreement with his point of view, but differ from him in one or two particulars. I should like to make those differences clear. In mathematics we must obviously teach the student certain techniques. Naturally the emphasis will be on those techniques which are of particular importance to the physicist. This means that large branches of pure mathematics which are normally taught to the mathematician will be omitted ; but it is much more important to do something in addition to teaching the techniques. We have to show how mathematics is used in physics, and in particular how the physicist translates the fundamental assumptions which he makes—sometimes he calls them the laws of nature—into mathematical terms, and conversely—and this is just as important—how a mathematical equation or expression which represents a physical situation can be translated into ordinary language.

So often in teaching mathematics and physics we do not do this. Often the lecturer in physics covers the blackboard with mathematical symbols before he has expounded the physics of the problem. I believe that it is necessary to start with the physics first. Unless your physical conceptions are right or your models are clear you cannot go on with the mathematics.

Often I am approached to help students or staff with some problem which they think is mathematical. They usually have to explain to me what the problem is, and it is there that the real difficulty arises ; the questioner has to explain in English what the physics is about, and it is often obvious that he has not understood the physical situation fully or aright. Once it becomes possible to express the physical situation in English it is usually easy to express the English in mathematics. It is this which we must remember when we are teaching physics.

There is a further point about the syllabuses. There is a tendency to overcrowding in all our technical college courses and syllabuses. This is a real danger, and it vitiates all the education which we are trying to achieve. It is constantly necessary to examine whether we are attempting to deal with too many facts, to the exclusion of the underlying principles. We all say, of course, that we want the inessentials left out, but we cannot get much agreement on what the inessentials are. It is generally agreed, however, that the understanding of physical principles is what is desired, rather than a mere knowledge of facts.

I think that it is worth remembering that basic principles, as well as the elements of scientific method, can be taught with very simple facts and without assuming any great mathematical equipment. As I said earlier, the mathematical theory, though important, should occupy a secondary place. It is the phenomena in physics which are primary, and insight into them is the great gift which the eminent physicists of our day and of earlier times had. I do not think that we can teach physical insight ; either you possess it or you do not. That is why there are so few good researchers. I think, however, that we can help students to develop an appreciation of what physical insight is by a clear exposition in non-mathematical terms of the physical principles involved.

I want to say a little about liberal studies. In general I agree with what Sir John Cockcroft said yesterday. On the other hand, I do not think that we have faced the fundamental problem of making a training in physics a real education. Members of the Education Group will remember that a few years ago the present Vice-Chancellor of the University of Bristol said : "We customarily talk of a classical education and a scientific training, and we have got into the way of assuming that there is little training in the former and still less education in the latter." Until physicists have faced this problem we shall still, to my mind, have to inject elements of liberal studies into our technical college courses.

That is why in the sandwich courses at Acton which we have started recently, we

have definitely included such courses as English and social studies, and something that, for lack of a better term, we have called the fundamentals of science, which includes an introduction to scientific method and the history and philosophy of science. It is difficult to get staff who can teach this sort of course, but one of the good things about our deliberations on this matter has been that the staff are beginning to learn together, and a start has been made. Professor Lipson said this morning that he did not feel that he could introduce subjects of this kind into his course, but he then gave us very good examples of how he did it. Essays such as he described are a valauable element in work of this kind.

I now want to say something about numbers. Professor Blackett referred to the Barlow Committee report and to the way in which the universities had expanded their accommodation and increased the number of their students in the post-war years. We all know that physics departments in some universities are four times as big as they were before the war. I got the impression, from what Professor Blackett said later, that he thought that they could still go on expanding and could realize the increase from 10,000 to 20,000 graduates a year mentioned in the most recent report. I am beginning to doubt this. I am glad that Imperial College is to have fifteen million pounds spent on it, and that Professor Blackett will get the facilities he wants, but I do not think that the expansion can go on there without taking students from other institutions. Indeed, what has happened in the post-war years as a result of university expansion has been that the technical colleges have been denuded of their degree courses, so that we have a situation in which the universities are full and the senior technical colleges are empty. When I say " empty " I do not mean that they have no students at all, but the full-time degree courses are almost empty and in many technical colleges have disappeared. This has come at a time when, as the report of the Institute shows, university physics departments are not full, and of those who go up to the university twenty to twenty-five per cent fail to get the honours degree in physics which they hoped to get when they entered.

Where are the extra scientists and applied scientists and engineers to come from ? We may hope to get a few from the arts side, from students brought up in the arts and in classics who turn over to science, but the difficulty about this was very well expressed by a schoolmaster, Mr. Gough, yesterday. Secondly, can we persuade more of the boys and girls who leave the grammar schools at sixteen to stay on ? Headmasters and headmistresses feel that something should be done to persuade more of these boys and girls to stay on at school. Of those who leave at sixteen we recapture some later because they come to the technical colleges and join national certificate courses. They may go on to a higher national certificate course and they may even take an external degree.

The boys and girls who leave school at sixteen, or at eighteen or nineteen, and go into industry, are a special responsibility of the technical colleges. Of those who leave school at eighteen or nineteen, I have been surprised to find how many have university entrance requirements. One industrial firm near Acton Technical College recruits apprentices at eighteen, of whom many have three advanced level subjects at least, and the usual number of ordinary level subjects ; but for various social and economic reasons these boys do not go on to the university but go straight into industry as student-apprentices.

It seems to me that these are the students who are the potential members of the sandwich courses which so many technical colleges are now arranging. It is hoped that the students will qualify for the new diploma in technology which has been instituted by the National Council for Technological Awards, of which Lord Hives is the Chairman. I shall not go into the details of these courses, because most of you know about them, but in the main they are sandwich courses extending over four or five years, and in each year the student spends six months in industry followed by six months at the college.

I believe that this is one of the greatest advances in technical education in our day. It is going to have a great influence on the

teaching and educational outlook of technical colleges generally. Into these courses there will be two streams ; firstly the boys who have left school at eighteen, and secondly, some of those who left school at sixteen, took an ordinary national certificate course at a technical college and have shown that they are of Dip.Tech. calibre. One special problem will arise in the first year of these sandwich courses. The two streams will come in not with different abilities—their abilities will be much the same—but with different attainments, and it is one of our educational problems to deal with these two groups in one course.

There are also difficulties in recruiting students for these sandwich courses. One of the difficulties is that sandwich courses are new in the training of scientists. We can persuade engineering firms to release their engineering apprentices for these courses much more easily than we can persuade either the same firms or similar firms to release their apprentices who are doing work on the scientific side. But it is not as difficult now as it was a year ago, and it is certainly much less difficult than it was two years ago. I believe that sandwich courses in applied physics of this kind will grow, and that they will be one of the most important functions of some of the senior technical colleges, and that they will be able to contribute quite significantly to the increase in the number of trained physicists of graduate standard.

A final word on the question of numbers. Reference was made yesterday to the "bulge" of students going through the grammar schools now, and which will reach the universities in a few years' time. I am glad that the technical colleges have started these sandwich courses at this stage ; they will be prepared to deal with a bigger flow of students when the bulge reaches university age.

Professor H. Lipson (*University of Manchester*) : I should like to give a few grains of comfort to Dr. Topping about numbers. I think that he is under a completely wrong impression about what is coming to him. In my experience, as you may have gathered, my department is rather marginal and it has been difficult to get students. In the last few years our average has been about eight entrants each year, and sometimes fewer. This year we are full. We have just taken as many students as we can take in, and applications for next year are coming in at about six times the rate of this year. He will have plenty of students before Imperial College can build its wonderful extension !

Dr. J. Topping : When I talked about numbers I was not thinking of Acton only. We started with nine last year, and I think that we shall have fifteen to twenty in January. I am concerned about numbers as a whole in the country.

Professor H. Lipson : Numbers are increasing. My daughter's school usually sends eight or nine people each year to the universities. Last year they sent fourteen, and this year twenty-three. Judging by reports from other schools the numbers are increasing in about that ratio. It is most encouraging.

Mr. K. D. Barritt (*Ewell County Technical College*) : Mr. Burnett stated yesterday that in many cases the physicist has taken over the engineer's job. It seems to me that one of the aims of the applied physics course is to fill the gap which exists between the physicist and the engineer. Is this gap really necessary ? I suggest that if the average three to four year engineering course and the three to four year physics course had some sort of common basis to their syllabus, so that the first two years were spent in treating the same topics, although perhaps in a different way, this gap might be overcome. This idea would have two advantages. First, it would give a degree of flexibility for young students to decide, after two years on the course, whether they wanted to pursue physics or engineering. I am sure that most boys of eighteen are not in a position to decide their ultimate future. Second, it would bring home forcibly to all concerned that physics and engineering are not two completely different subjects, but are in fact two completely different ways of looking at the same subject.

This morning it was suggested that the cost of sandwich courses should be met by the local authority, i.e. the ratepayers. It costs about two thousand pounds to produce a sandwich graduate. Industry, I believe, spends something like three hundred and fifty million pounds a year on advertising. If a one per cent reduction were made in this expenditure and the money so saved paid into a central fund, it would pay for the cost of about seventeen hundred sandwich graduates a year, benefiting industry, the student, and the community as a whole.

Mr. E. R. Davies : I do not know that everyone will agree with the economic principles of the last speaker !

Mr. F. Y. Poynton (*Northampton Polytechnic, London*) : I heard with great pleasure Professor Lipson's talk, and I find myself in complete agreement with him. I do not think that he need hesitate about the use of the word "applied" in connection with his course. I see his point about its influence on the recruitment of students, but in America and on the Continent there are very good precedents for courses of the highest standard having the word " technical " or " applied " attached to them. Much of the trouble is due to the fact that there is a wrong conception of what people who wanted to run courses of this kind have desired to do. If such a course consisted of cutting out a large part of the time devoted to the fundamentals of physics and injecting in its place a sheer mass of factual information about ironmongery I should be wholly against it, as I think anyone would who was concerned with the teaching of physics at all ; but if it can be made clear that no one wants that and that it is merely a question of emphasis it will be another matter. After all, a great deal of selection has to be made in any physics course.

Most of us will have been bombarded during the last year by advertisements for a handbook of physics in some fifty-four volumes, the first one to cost about eight pounds and to contain an astronomical number of pages. In any physics course in any university or major technical college concerned with courses of this general standing there must be a great amount of selection, and so long as the fundamental fact is not lost sight of that the basic object is to develop the fundamentals of physics there will be a great variety of ways in which this can be done. Immediately after the war I thought that something on these lines could be done very quickly, and that we should be able to experiment with courses of this kind at my own and other colleges. We have been very disappointed. Much of the last ten years has been spent in discussing this matter. I felt inhibited from the beginning because of the question of the award. It seems to me very necessary to have some award which will attract students of the right calibre. I was therefore very much encouraged by the action of The Institute of Physics recently in agreeing so strongly to support several courses of this character. That has given us in some of the technical colleges a great deal of encouragement, and I can assure the Institute that we are out to justify it and I believe that we can definitely do so. It will be, I think, on lines not very different, certainly so far as the spirit of it is concerned, from those so excellently indicated in Professor Lipson's address.

As a further appendix to Professor Lipson's remark on the question of numbers, I would say that I was surprised to hear Dr. Topping talk about small numbers in our technical colleges. We seem to be too crowded with people. I know that largely they are not the grade of student about which we are talking now, but at the moment we have a steadily rising number of students taking degree courses in engineering. The number sank after the bulge of a few years after the war, but it is now showing a marked upward turn. My colleagues who are concerned with organizing sandwich courses in the engineering field seem at the moment quite enthusiastic about the response which they are getting. In physics I do not expect to have the numbers that my engineering colleagues are getting, but the report which I have to make is very much like that which Dr. Topping has made. We started with a dozen;

one has got married, so that now there are eleven. We shall certainly have appreciably more for the second course starting in January, 1957. After our experience of last year I hesitate to say just what the number will be, but it seems likely to be reasonably encouraging. As I say, I do not suppose that on the applied physics side we shall get the response that my engineering colleagues expect, but from the contacts and conversations that I have had with firms and other organizations I feel I can endorse the comments which Professor Lipson has made.

Mr. E. M. Wareham (*W. H. Sanders (Electronics) Ltd., Stevenage*) : Several speakers have used the composite term scientist-engineer to describe a type of activity which is not research and not engineering but something of both.

May I contribute a few thoughts on this type of activity from the point of view of electronics design and development. I think that it is typified by creative thought, and concerned largely with the solution of specific practical problems of Applied Physics in terms of effective hardware of some sort. Clearly the scope of the knowledge required for this type of activity must range over a wide field from pure academic physics to production engineering.

I would like to suggest to you that this implies a definite educational process consisting of a scientific basic education which has been followed by an engineering training. I think also that the scientist-engineer should have a good grasp of industrial organization and management. This seems to me to define what might be called a technological education, and I attach equal importance to all three of its aspects.

Dr. H. H. Hopkins (*Imperial College, London*) : Dr. Thomson appears to have been brought up in a mathematical school on the type of problem which begins : "Consider an elephant whose weight may be neglected. . . " I think that, like most people who have given up their first love or their first beliefs, Dr. Thomson is very unkind about mathematics. The simple fact of the matter is that mathematics, and advanced and sophisticated mathematics, is being used increasingly in all sorts of fields—problems of heat transfer, vibrations, sedimentation, problems in statistics, fluctuations and so on. There are very many new applications of the more difficult and sophisticated mathematical techniques, and in many cases they seem to be more difficult and sophisticated in what we would call applied physics than they are in physics itself. I can cite as an example the fact that at Imperial College the engineering schools have asked the mathematicians to give them lecture courses in the third year on tensor analysis and complex variable theory. Neither of these is treated as a formal subject at all with our honours physics students, yet here we have very applied subjects and they want tensor analysis and complex variable theory. There can be no question, therefore, of applied physics (if we are going to call it that) dealing with mathematics in a feeble sort of way.

Something has been said about the close connection between the subjects in physics, such as damped oscillations in mechanical, electrical, atomic and optical systems. To my mind, the link here is the theory of these processes. The actual experimental arrangement in which one gets damped oscillations in a mechanical system or in an electrical system are quite different and the methods of measurement are quite different. This suggests, to my mind, that the place in which to unify all these things which are common in physics is in an elementary course in general theoretical physics. I feel that this unity of physics is a unity of the concepts of physics and of some of the mathematical methods, and it is therefore in an elementary general course in theoretical physics that these things can be dealt with, and such a course must be part of a course in applied physics.

With regard to the name, I think that "applied" physics suggests something other than what we should mean. It suggests the old-fashioned idea of someone having done a nice piece of physics, and then someone else comes along and says : "We will apply it." This is not the case at all, and it seems to me that "technical" physics would be a better

word. I did not come here merely to advocate the use of a different term, but I do feel that the term "applied physics" gives a wrong impression, and to my mind at any rate "technical physics" is a very much better term to describe what we mean by this subject.

One remark about the numbers of students. I do not share the pessimism which some people express about whether these students *can* be found, but I do share the general pessimism of whether they *will* be found. I should like to give three examples of people, two of whom have been research students of mine and the third a mathematician working in industry. Each of these three failed the entrance examination to a grammar school at the age of eleven. All of them were fortunate enough, for various reasons, actually to enter grammar schools. One of them got a Ph.D. and is now a senior scientific officer in a Government establishment. The second got a Ph.D. and then immediately obtained one of the few senior Government research fellowships awarded each year. The third went to one of the London Polytechnics as a part-time student, got a second in mathematics and is now a graduate mathematician. These are three examples of people who failed the entrance requirements for grammar schools at the age of eleven. Because of this, I think that the students for whom we shall be looking can be found, but I share the general pessimism about whether they will in fact be found.

I am depressed by the general attitude that it is the rather inferior, not-so-good student who is going to be drawn into technical physics. The problems in technical physics are extremely difficult ones. The academic physicist often has the same choice as the mathematician; he solves the problems which he can solve. The technical physicist is faced with the stubborn, brute facts of nature and often an equally stubborn employer who tells him to do something about it. This means that we require not only a very large number of people in the technical assistant grade and the ordinary sort of graduate but also a considerable number of absolutely first-class men. If you run your technical physics in an apologetic sort of way in institutions which are prepared to take students who cannot get into places which, for right reasons or wrong, have more kudos, if in the technical colleges you are going to teach technical physics and the only people you get are those who have not been able to get into universities, then there is going to be a serious shortage of these first-class men that are needed in technical physics.

The way in which to attract first-class men is by having a first-class research department. It has been said repeatedly in this conference that the exciting thing about physics—not so exciting, very often, when you do it—and the thing that attracts students is research work. It is a simple fact, which should not be forgotten, that the kind of things that you do when doing research in technical physics are precisely the same as those that you do if you are doing pure physics. If you have an amplifier, you do not ask whether it is an applied physics amplifier or a pure physics amplifier and it is the same with other matters. The kind of thing that you do in both types of research is the same; it is the end which is rather different. We must not lose sight of the fact that really first-class research departments are needed in departments of technical physics. Moreover, no subject can live without a literature, and I am very glad to see that The Institute of Physics has taken a bold and imaginative lead in this respect and has started publishing some small booklets on applied physics. I think that this should be continued and extended.

Professor A. J. C. Wilson (*University College, Cardiff*): A good deal has been said about the problem of numbers, and also about the humane education of scientists and technologists, and there has been some bewilderment about why the United States and Russia can produce about three times as many scientists per thousand of the population as we can. I do not know anything about the educational system in Russia, but my school education and part of my university education were in Canada, and more of my university education was in the United

States. I think that the problem of numbers and the problem of the humanities are somewhat tied up.

In the British educational system I find a large number of merits, and I am not at all sure that to adopt what happens on the other side of the Atlantic lock, stock and barrel would be an improvement, but there are some points about the North American educational system which seem to me to have advantages. The first is that grammar schools and secondary modern schools are not separated to anything like the extent that they are in this country. The children are all educated together up to the time that they leave school. That has certain social advantages into which it is not necessary to go, and it also means that there is no 11+ examination, so that children here who are unlucky in that examination or who have not the right sort of mind for doing intelligence tests would not, under the American system, be cut off from further education almost irrevocably. The disadvantage is that teaching has to go more slowly, so that by the time that a child reaches the end of his school years his level is about that of our ordinary level examination instead of the advanced level ; but at that time you still have the whole school population, and a great number of them can still make the choice between arts and science, whereas in the British system it seems to me that when a child enters a grammar school, by the age of about thirteen he is committed to an arts career or a science career. Changes after that age are possible, but rare.

At that age the child is, I think, very much influenced by the personality of the teachers. If he likes the English teacher he will go in for arts and if he likes the physics teacher he will go in for science. The chances are that the English teacher will be someone with first-class honours and that the physics teacher will have third-class or a pass degree; so that many able boys, capable of doing well in science, are diverted to arts. There are a large number who are born to be arts students and a similar number born to be science students, perhaps twenty to twenty-five per cent of the school population in each case ; but the middle fifty to sixty per cent can go either way and get a 2·1 if not a first. This forcing of the choice between arts and science at an early age is, I think, one reason why we do not get as many people as we would like going to the universities for science. If we could make the proportion of grammar school pupils taking science seventy-five per cent, instead of the present fifty per cent, I think that we should get a fifty per cent increase in the science students at the universities without any great drop in quality, because I think that half the people who do arts would do just as well in science.

By carrying the study of the humanities up to university entrance and even beyond, with English as a compulsory study—in my first year at university I spent many unhappy hours writing essays on subjects chosen from Milton, which I am sure was good for me—the difficulty of the science graduate being trained but not educated would largely disappear.

Mr. M. Milbourn (*Imperial Chemical Industries Ltd., Metals Division, Birmingham*) : There is room in industry for both the specialist and the general practitioner, but the specialist generally evolves himself ; by his work and by his interest he shows that he has a useful contribution to make to industry in his own chosen narrow sphere. On the other hand, the general practitioner must have a certain amount of mobility or ubiquity, for during his useful working life of about forty years, he will be expected to apply his knowledge to a wide variety of problems. He should, therefore, have a broad fundamental background and the ability to think clearly and constructively. Not only has he to work on problems presented to him, but he should be able to see lines of investigation in which his own particular training and abilities can make a real contribution to the activities of the company with which he is engaged. The profit motive does not debase investigations, but makes them very satisfying when they are brought to a successful conclusion, which adds generally to the standard of living of the country.

It is quite unlikely that more than half of a graduate's working life will be devoted to

physical investigations, and the non-academic activities will increase as the years go by. Industry is very conscious of this fact and, in engaging graduates, tries to visualize what they are going to be like in, say, twenty years' time, so that there is a good chance that they may advance reasonably and according to their own expectations. What therefore are the qualities that industry looks for ? First, of course, a thorough knowledge of the chosen discipline, gained through formal instruction and experience, and ability to apply that knowledge. Then there are the more personal attributes of co-operativeness, initiative, judgement and leadership. These qualities are not subject to scientific method, although some of them have a fairly large technical content, and can therefore be learnt to a certain extent during formal training.

In acquiring these attributes, the possible value of a period of national service should not be neglected. Furthermore, the university graduate is often a better all-rounder at the age of forty to fifty than the man who has gained qualifications by part-time education, but there are, of course, many exceptions. Nevertheless, the seeds of acceptable personal qualities can clearly be sown during a university course, presumably by extra-mural activities and by contacts between inquiring minds. Sandwich courses in technical colleges offer a great opportunity for the same sort of broad education, and I hope that sandwich course students will be given opportunities to develop their personalities fully.

Dr. A. G. Peace (*North Staffs Technical College, Stoke-on-Trent*) : It has emerged from the remarks of most of the speakers that a physicist to be of use in industry must have, in addition to a desirable memory of his subject, an understanding of it and some experience in its use. Whether this experience should be gained before his graduation or after in a university or in industry is open to some argument. I suggest that there are circumstances in which each course has its own merits and is more satisfactory.

Let us consider the three main partners in this business : the university, the technical college, and industry. First, the university. Since it is obviously impracticable for a university to cater, after the first degree, for all branches of industry, I suggest that it should do so for none. It should, however, provide postgraduate training for its own students, by which I mean those who will prove to be of prime importance in the furtherance of academic research work, and, if you like, those who will become university scientists. That is not to say that an undergraduate should not, in the course of his career, be taught the practical techniques of classical physics and classical measurement. It is indeed surprising that, physics being a science based on measurement, the science of measurement is so infrequently taught in universities. I agree with Professor Blackett that industry needs numbers more than anything else at that level, provided that those large numbers of people really understand fundamental physics. Too often I feel that the criticism is valid that lecturing in universities and other places is a process of transferring information from the lecturer's notebook to the student's without it going through the brain of either.

I should like the university's function to be, in addition to this giving of a general and basic training in physics, a very careful selection of graduates, much more careful than at present. Universities should be more " choosy " in their allocation of research grants and give them only to those students who are likely to make academic research their career for life. That is very difficult, I admit. I also feel that there should be considerable extension of the scheme by which a graduate in industry can go back to university some years after graduation, not necessarily to his own university, to acquire further knowledge of academic progress in his own field after he has had some experience of industry, so that he knows roughly the kind of problems that he may be expected to face. That is done so[me] times, but it is not easy. Universities w[ould] have room for such students if they did not clutter themselves up with so many run-of-mill Ph.D. students, many of whom, as we have heard in this conference, may not be doing very useful work.

Secondly, what is the role of the technical college ? In this country there is a large number of major technical colleges which are as well equipped as universities for the teaching of classical physics, and probably electrical and mechanical engineering, and I am sure that it is generally agreed that they do a good job with possibly very largely second-rate material ; but I am disturbed by reports that I receive from my colleagues in electrical engineering that The Institution of Electrical Engineers seems to be tending to make it exceedingly difficult for a man with a higher national certificate to become a member of that Institution, and I am sorry to say that I fear that The Institute of Physics is going on the same lines.

The job of the technical college is to train students who are receiving their theoretical training in the technical college alongside their practical training, their applications training, in industry. I see nothing wrong with this, but I think that it should be kept to the technical colleges ; I do not think that the university courses should in general try to do other than they are doing in this country at the moment with the single possible exception of Manchester College of Technology which has a unique position. It seems to me that Professor Lipson's scheme is an admirable one for a sandwich diploma course.

Thirdly, there is the role of industry. I think that industry cannot escape some blame for the present position in the production of physicists. The technical colleges have, or should have, much closer ties with industry than have the universities, and industry must accept considerable responsibility. Too often we hear of courses put on at the behest of industry and on which time and money are spent on apparatus and in drawing up syllabuses, and then, when the time for enrolment comes, we get two students, and not the two originally promised either !

Mr. G. C. Eltenton (*Shell Refining and Marketing Co., Cheshire*) : It is not clear to me whether my fellow industrialists are satisfied with the quality of those graduates who present themselves for interview or of those who are finally selected. I find that I have to reject about one half of the candidates on the grounds of lack of fundamental understanding of quite elementary physics. Industry sees the product from a very wide cross-section of universities and while we are usually well satisfied with some, there appear to be others where change would be beneficial, to put it mildly.

I was delighted to hear of the stress put on long-term experiments in Professor Lipson's course. We usually ask a candidate to describe some experiment that he has enjoyed. Not infrequently a candidate expresses surprise that he should be expected to enjoy any experiment and far too frequently he has only done a series of well-drilled and emasculated afternoon exercises. This may be called training ; it is not education.

We have heard much about the sin of " Compartmentalism." It certainly exists. Out of 24 candidates examined this year not one had considered the similarity between a mechanically and an electrically oscillating system of the simplest kind. It is rather discouraging ; and one wonders whether the slight element of complacency which I think was detectable yesterday is justified. It is most wasteful to stress quantity if, by obsolete methods, we are neglecting quality. Where do these rejected candidates go ? Do they gravitate into the smaller industries who can ill-afford the training which will be needed ? Is this one of the reasons for the reluctance of large sections of British industry to employ scientists properly ?

Perhaps the most disturbing feature of all is the loss of curiosity observable in so many candidates. Presumably as children they were almost unbearably inquisitive. Somewhere in the educational machine erosion has taken place. They have almost forgotten how to ask questions. We have heard too little at this conference from the schoolmasters. Are university entrance requirements a deterrent to stimulating teaching ? Is knowledge crammed in and curiosity drained out ? How many of us in this hall have drowsed through some appalling university lectures which it has been expedient to attend ? Can we afford this " luxury " ? Is there no

alternative which would be economical in staff yet as stimulating as a good tutorial ? I submit that perhaps the syndicate method, practised quite widely in industry but mentioned only once in these proceedings, might be a partial answer. Long term experiments are certainly another.

Professor G. D. Rochester (*University of Durham*) : I agree very much with what the previous speaker said. This is a matter to which some of us have given some thought. It is quite true, as Professor Blackett indicated, that most of the students who come through the honours physics schools are an excellent product and can be taken straight into industry, but we must remember that there are large numbers of pure science students who are outside honours physics and each year there are the students who fail at various stages in their honours physics courses. The problem which has exercised my mind a good deal is how to maintain the interest of these students. What type of course will make them best fitted for the needs of industry and society ? I think that this bears on what the last speaker said, that in the universities we are much too attached to the older forms of course. It would stimulate these students enormously if it were possible to offer alternative courses to the normal traditional courses which are usually of the type physics-chemistry, physics-mathematics, and so on. I would like to see a two subject degree in engineering and physics, or even in two parts of physics. This kind of degree is offered in engineering in some universities and I do not see why it should not be possible to have it in physics also. The type of degree I have in mind would of necessity be rather more technological than " pure." This degree might, in fact, be properly termed " Applied Physics." I am sure such a degree would have the effect of stimulating a large number of ordinary degree students who are failures in the ordinary university sense in the honours physics schools.

Professor E. G. Cullwick (*Queen's College, University of St. Andrews*) : As a professor of electrical engineering I feel a little diffident in contributing to this discussion. I have listened with great interest to the accounts of different courses which have been given, and I have heard many interesting views and some rather astonishing ones which may have caused a shudder in the portraits on these walls. I suggest that a solution of one part of this problem of applied physics can be found by looking round this room, whose portraits illustrate the intimate marriage between physics, natural philosophy and electrical engineering. Without the work of the pure scientists there would be no electrical engineering, but I must confess that if men like Ferranti and Hopkinson had ever heard it suggested that it was not the function of the engineer to design creatively, sparks would have flown of quite a high voltage !

With reference to the comments of the last speaker, it may be of interest to mention that we have in St. Andrews University, in Queen's College, Dundee, the only course which is called applied physics which is run by a professor of electrical engineering. This course is now four or five years old, and there were several reasons for starting it. One was that I felt, after about a quarter of a century in Canada, that there is a curious sort of social climate in Britain which does not value a career in applied science in the way in which it values a career in pure science. I found that this is corroborated in many Government reports, which deplore it. As a possible corrective to this, I thought that it might be a good idea to provide students who had, perhaps on unwise advice, started a course in pure science, with an opportunity to change their minds after two years in the university, and also to provide a course which is a co-operative venture between departments of pure and applied science.

We accept students who have had two years of pure science, taking what we call their " specials " in mathematics and physics, having taken four science subjects in their first year on the general level, which is the Scottish system, and then take them into the electrical engineering department. In a four-year honours course, their advanced work comes after a thorough grounding in mathematics and physics but they do not take

traditional engineering subjects such as theory of structures and so on. On the whole it works very well. They get an ordinary degree in mathematics and physics and take the same honours examination as our students in electrical engineering who specialize in electronics and electrical communications, writing a thesis on a laboratory project in the final year. We have called it " applied physics " because we could not think of a better name, but we also add the word " electrical." More and more students are taking it.

However, I do not think that it is ideal. It is a course made up of available courses, so it is not so much what is desirable but what is possible. We are now making plans to modify it, and intend to include physics courses up to honours standard. At the moment physics as such stops at the ordinary degree standard, and there may be the criticism that the course is neither fish, fowl, nor good red herring, providing neither an honours-standard physicist nor an honours-standard engineer. However, industry seems to like it and all our graduates in it have many offers.

Mr. E. B. Pearson (*Royal Military College of Science, Shrivenham*) *:* Reference has been made to a remark made yesterday, that in many cases the possessor of a higher degree is not so valuable to an industry as the possessor of a first degree who goes straight into industry. If that is true it is a very disturbing thought, because a man may spend two, three or more years in taking a higher degree, thinking that thereby he will get a better job in industry than those who go straight into industry with a B.Sc. In some cases men may be forced to take their higher degree by work on a subject which may be a highly specialized one, because the school of physics of the university concerned wants to be famous for papers in that field of physics, which may in some cases not be of much use to industry.

Large industries have their own research departments and would hardly be likely to want to farm out their problems to the universities, but the smaller firms, and some firms which are not small, do not have their own research department, perhaps because most of their work is fairly clear-cut and it is not economic for them to run a research department ; but every now and again they probably get problems on which they would be glad to have research done. Is there any way in which the universities can be informed of these problems, so that a man who wants to go into industry, but at the same time wants to get his M.Sc. or Ph.D., can be given a problem which is obsessing some manufacturer and which he could solve for him ? That would mean helping the industry and helping the man to get his degree, and instead of living in a sort of vacuum he might visit the industry once a month, say, in order to see exactly what the industrial work was like. If the university says it cannot do the work because it has not the apparatus, presumably if the industry really wants the work done it will be willing to provide the necessary apparatus on loan.

It seems to me a most frightful indictment, if it is true, that an appreciable number of higher degree men are not being a success in industry, when on the face of it they should be very much better than the others. I wonder whether it is possible for the university student to make a direct request to be given a problem coming from an industrial concern ? People at the M.I.T. to whom I have spoken tell me that quite a number of the students there do research work for higher degrees on problems sent to the M.I.T. direct from industry. I am not sufficiently in touch with that side of industry to know whether or not I am asking a silly question.

Mr. H. J. E. Anscombe (*Harrow Technical College*) *:* I hesitated to speak earlier, because my contribution may bring the conference down from the rather high level on which it has been up to now, since it has been concerned so far mainly with the provision and content of courses for honours and other graduates ; but the conference is concerned also with the question of supply and demand, and I share the opinion which has been expressed about numbers, to the extent of regarding numbers as of some importance

even when compared with quality. Sir George Nelson also mentioned a question which is related to this when he asked whether or not graduates were being properly employed.

That brings me to the point that there must be a demand for various grades of physicist in the way that is already recognized amongst engineers. I have some contact with applied physics in that we run national certificate courses in applied physics which are outside the terms of reference of this conference. Although it is improbable that my college, in view of its large and well-established neighbours, will run courses for the Dipl.Tech. or part-time degree, I am convinced that it has a useful part to play. We have at the moment in our applied physics courses a number of students who last year would have done G.C.E. courses. Now an engineering diploma scheme, with which I have had some experience, selected its diploma students from the national certificate course, and I feel that there is ample scope for doing the same type of thing in the corresponding levels in applied physics. If we can produce not only people who have honours graduate qualifications in applied physics, but also some with a lower qualification, they can well relieve the better people of some of the more humdrum work.

More than one speaker has suggested that in technology we forget the humanities. My experience in the colleges in which I have been is that, possibly because the technical students have outnumbered the arts students, the keenest debaters and the people who have run the various societies have been technical rather than arts students. That may be because it has been more of a holiday for them !

One speaker referred to graduates at ages over forty showing up better than others of that age. Graduates who are now over forty passed through the universities when opportunity and selection procedure were somewhat different from what they are to-day. It may well be factors other than the university training which have contributed to the qualities observed in the graduates.

Dr. H. R. Lang (*The Institute of Physics, London*) : I wish to make two points for the record. The first is that the Imperial College of Science and Technology, up to about 1925, had a course started by Professor Sir Charles Boys and carried on by Callender which was almost identical with the one described by Professor Lipson. Physics students took machine drawing and electrical engineering. It might be worth while looking up that course.

The other point is in regard to the use of the term " applied physics." We discussed this with the Ministry in the early days of the national certificate scheme and were advised that a national certificate in physics (without a handle) would not attract students. We considered the terms " technical physics " and " applied physics " and so on, and eventually came down in favour of " applied physics." The American journal with which you will be familiar was originally called *Physics*, and perhaps because it did not sell too well it was decided to call it *Journal of Applied Physics* ; now it has a large circulation among non-physicists !

Mr. P. Gough (*Brighton College*) : I want to reassure Dr. Topping : in addition to the bulge which is about to arrive there is also a trend, a trend to take science, which is most noticeable in my own school. We have to make scientists less frightened of industry. When I left the university I should have been terrified if anybody had suggested that I should go into industry, but if it had been suggested that I should do some research I should have been delighted. To avoid this feeling of fear I suggest that before the students go to the university they should have some contact with industry. That will also arouse their interest. I think it was A. N. Whitehead who suggested that before anyone went to the university he should go for at least a year to the job which he eventually meant to take up. That would perhaps be a solution for the problem of the four-year course and for many of the other problems raised yesterday and to-day. If boys on leaving school could go into industrial firms, and into as many firms as possible, chosen by their future universities, to see what industry needs and what they will need to know in industry, they could then learn their

physics *and would have the will to apply it.* If you are going to do applied physics you must learn mathematics and physics *and* have the will to apply it.

Professor J. S. Rankin (*Royal College of Science and Technology, Glasgow*) : I should like to thank Professor Lipson and Professor Gavin for their excellent discourses. The question of the name " applied physics " has been raised but Dr. Lang has given the answer there. It is only a name and I think it is difficult to find a better one. I considered " technical physics " and also " industrial physics," but I had in mind that there is another basic science—chemistry—where we have the pure chemist, but the applied chemistry degree was introduced about forty-five years ago. We are only following suit. These things are not important, and " applied physics " is quite a good name.

Professor Gavin was very modest about it and said that he was just experimenting. I got over my experiments four years ago; I think that it is a good thing and I am glad to know that industry is supporting the idea. It is not an experiment now ; it is established.

I hope that we shall leave this conference with the conviction that there is room in the university for a pure physics course and for a course in applied physics. One must not dabble with the pure physics course and say that it is applied physics ; what is wanted is an independent course in applied physics. If the universities do not want to do it, now is the opportunity for the technical colleges to come in and do something on these lines.

CLOSING REMARKS

Mr. O. W. Humphreys : Nobody belittles the importance of numbers. Obviously if we can produce more scientists of the present standard we shall increase the scientific contribution to industry ; but surely in scientific work as much as in any other branch of human endeavour productivity is important. There is just a risk, I think, that we may be bemused by this question of numbers and may use the lack of numbers as an excuse for not using properly the people that we have. When you think of productivity in any branch of industry you think first in terms of fundamental factors such as processes, plant, layout and so on. In thinking of productivity in terms of scientific contribution to industry, we obviously start with training. Here I would digress a little and say that I think that we in industry are a little too unappreciative on occasion of the way in which our colleagues in the educational world are willing to meet us so that we can discuss their problems with them and tell them how we think that they should tackle them. Would we be equally broad-minded, I wonder, if they suggested that they should come to see us and discuss the way in which we should use the people with whom they supply us ?

That this is a combined operation is the theme on which I would like to close this conference. It is a combined operation at all stages, because the education of our scientists never stops. The nature of the contribution which the educational side and the industrial side have to make varies as the man grows up. At the stage of the graduate course, industry's contribution is to influence the syllabus ; to try to draw up the syllabus would be an impertinence. Our function is to perform the rather difficult task of explaining our needs to those who are going to train our young men. I say that it is a difficult task because we find it so difficult to define our needs even to ourselves ; and, that being so, perhaps it is not surprising that we sometimes find it difficult to find words in which to convey our half-formed thoughts to other people.

Immediately after the graduation stage industry can help very much by supporting the postgraduate instructional courses to which the Ministry of Education has recently given its blessing. My own experience is that where good postgraduate courses are available at a high level in a specialized field in the university they are invaluable, and we should not hesitate to send people back to the universities, people in, say, their early thirties, for

twelve months to take a special course. We have sent men from my own laboratories to Sheffield and to Cambridge and also to America in the last year or two, and there is certainly no philanthropy involved ; we do it because it pays, and pays very handsomely. The feedback between industry and the universities about which we are always talking comes into play again and again. We stimulate the university to produce a course and they do so. We must then make use of it, and, having made use of it, the course will itself develop as the university finds out exactly what it is that is required.

The other way in which we can help one another in this combined exercise is that of encouraging an interchange of good men between the two fields.

There are, of course, many other things which affect this question of productivity which there is no time to discuss, and in any case it would not be proper to dwell on them now ; but I would like to refer back to one which I mentioned in opening the conference, the new way of using scientists in closer collaboration with engineers, because I am convinced that that gives a bigger increase in productivity than almost any other action which we can take. Do not misquote me ; I do not say the use of all scientists in that way, but the use of some scientists working in close collaboration with engineers on specific projects. It pays handsome dividends. There is also the question of the proper use of supporting staff, which raises the question of the training of the supporting staff, which is in itself a very important subject.

We have to-day been talking much more than we did yesterday about actual courses, and the sandwich course has loomed large in our discussions. I am rather a late convert to the sandwich course. I needed no conversion where the sandwich course for engineers was concerned, because I recognized at an early stage the need for it ; but when it was a question of sandwich courses for physicists I thought first of all in terms of the theoretical physicist, the man who was going to be an outstanding research worker, and it seemed clear to me that the sandwich course was not for him. There I am unrepentant ; but I believe that the sandwich course may be better than the full-time course for some types of men. I am not going to risk defining the types that I mean.

If the sandwich course is to be successful, I believe that we have to recognize that it is one continuous course, in which six months happen to be spent in the college and the next six months in industry. If we look on it as six months' training and six months' practical experience, six months' formal education and six months' doing the normal work of an industrial laboratory, I believe it will go wrong. The time spent in industry has to be planned just as carefully as the time spent in the university or technical college. I believe that we in industry ought to return the compliment that our friends in the colleges have paid us by coming to listen to us by going to them and saying : "Will you please help us to plan our half of the sandwich course ? " I believe that this is important from the point of view of the content of our part of the sandwich course, and important also from the point of view of the timing, so that the experience which we give fits in with the teaching which the colleges provide. I believe that with this collaboration some parts of the college course, such perhaps as methods of measurement, or some aspects of methods of measurement, could be given during the industrial time, thus making it possible for the colleges to include in their own part of the course more of the sort of thing that they are best able to offer.

If has been said by Dr. Richardson, and very properly, that this conference has yielded no clear conclusions. For that I am devoutly grateful, because if any clear conclusions had seemed to emerge I should very much have doubted their validity. Problems such as we are discussing are not solved on the basis of two days' talking. I am sure, however, that very many seeds have been sown and that they have fallen on very fertile ground. If that is so, the conference has achieved its purpose.

One thing, however, which clearly emerges is that we are not talking about the education of one type of person : that industry needs physicists for research, for development, for production and on the commercial side as

well, and that the training which best suits one may not best suit another. That does not mean that they do not all want to be physicists. In fact it would probably be more correct to say that the types of people who are likely to end up in these different tasks are different and, being different types, a common educational approach may not suit them all. They may need to have their physics instilled into their minds in different ways.

Professor Blackett said that it was very right and proper that the prize of a big research job should be held before the eyes of the undergraduate. I am a great believer in prizes as incentives, but I would remind you that four- and six-minute milers seldom run in the same race. One thing which has pleased me throughout this conference is that the signs of complacency have not been many. I am glad of that, because complacency builds very unsubstantial and very ephemeral halos.

Forthcoming Institute Meetings

May 13 North-Eastern Branch — At King's College, Newcastle-upon-Tyne, 5.50 p.m.

Branch Annual General Meeting

followed by

"*Physics and Physic*"

DR. J. M. A. LENIHAN, F.Inst.P.

(Regional Physicist, West of Scotland Hospitals)

May 22 London and Home Counties Branch — Ford Motor Co. Ltd., Dagenham

Summer Meeting

A party will leave Charing Cross pier by river boat at 11 a.m. to visit the Ford Motor Co. Ltd. works at Dagenham. Forms of application may be obtained from the Deputy Secretary of the Institute.

May 30 Non-Destructive Testing Group and Royal Aeronautical Society

At the Institution of Mechanical Engineers, 10 a.m.

Joint Symposium

"*The Significance of the Results of Non-Destructive Testing*"

Chairman : PROFESSOR A. J. MURPHY, A.F.R.Ae.S.

Principal Speakers :

S. WISE (Research Department, British Railways)
N. E. FROST (Mechanical Engineering Research Laboratory)
W. THOMPSON (A.I.D. Materials Division)
W. G. COOK (Rolls-Royce Ltd.)

The symposium is open to members of the Institute and the Royal Aeronautical Society. Non-members may obtain tickets from the Secretary of the Society, 4 Hamilton Place, London, W.1.

June 1 Education Group — The College of Aeronautics, Cranfield

Summer Meeting

Forms of application for the all-day visit to the College of Aeronautics, Cranfield, may be obtained from the Deputy Secretary of the Institute.

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON MARCH 5, 1957

An asterisk (*) indicates transfer from another grade

FELLOWS

*Atherton, Edward, B.Sc., Ph.D., Head of Dyeshouse Research Section, Imperial Chemical Industries Ltd., Manchester.

*Barker, Alan, B.Sc., Physicist, Thos. Firth & John Brown Ltd., Sheffield.

*George, Edgar, B.Sc., Administrative Head of Science Department, Wolverhampton and Staffordshire College of Technology.

*Gordon, Robert Louis, B.Sc., Ph.D., Principal Scientific Officer, Safety in Mines Research Establishment, Sheffield.

*Hughes, Howard Arthur, B.Sc. Principal Physicist, Western Regional Hospital, Edinburgh.

Hunt, Stanley Ernest, B.Sc., Ph.D., Sub-Section Leader, Nuclear Physics Section, Associated Electrical Industries Research Laboratory, Aldermaston, Berks.

*Kirby, Peter Linley, M.Sc., Chief Physicist, Welwyn Electrical Laboratories Ltd., Bedlington, Northumberland.

*Mack, Cornelius, M.A., Principal Research Officer, British Cotton Industry Research Association, Manchester.

*Parker, Robert, B.Sc., Ph.D., Lecturer, University College of North Wales, Bangor.

*Pilling, Herbert Vernon, B.Sc., Head of Science Department, College of Technology, Art and Commerce, Oxford.

*Roberts, Vernon, B.Sc., Principal Scientific Officer, Ministry of Supply, Malvern, Worcs.

Skinner, Herbert Wakefield Banks, M.A., Ph.D., F.R.S., Lyon Jones Professor of Physics, University of Liverpool.

*Stanford, Edwin Garnet, B.Sc., Ph.D., Head of Physics Division, Aluminium Laboratories Ltd., Banbury.

Thornton, Stanley, B.Sc., Ph.D., Lecturer in Physics, University of Durham.

*Wheatley, Bernard Miles, B.Sc., Ph.D., Assistant Physicist, Institute of Cancer Research, London.

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*Ellis, Jonas, B.Sc., Ph.D., Research Physicist, Marconi's Wireless Telegraph Co. Ltd., Essex.

*Ferrier, William George, B.Sc., Ph.D., X-ray Crystallographer, British Rayon Research Association, Manchester.

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*Brudenell, Granville Gordon, B.Sc., Technical Engineer, Bristol Aircraft, Ltd., Bristol.

*Brydon, George Morton, B.Sc., Research Physicist, The Plessey Co. Ltd., Northants.

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*Conn, Alexander, B.Sc.

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*Davies, David Keith, B.Sc., Research Student, University College of Swansea.

Dean, Paul Jeremy, B.Sc., Postgraduate Research Student, King's College, London.

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*Howie, Robert, A.R.T.C., Physicist, Robert McLaren & Co., Glasgow.

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*Morton, William Taylor, B.Sc., Research Student, University of Glasgow.

*Osland, Joan Corinne, B.Sc., Physics Mistress, Felixstowe College, Suffolk.

Page, Ernest Basil, B.Sc., Scientific Officer, British Insulated Callenders Cables Ltd., London.

*Palmer, Ronald William, B.Sc., Research Student, University College of Swansea.

Porter, Brian, B.Sc., Physicist, De Havilland Propellers Ltd., Herts.

Potter, Peter David, B.A., Research Engineer, Davey, Paxman & Co. Ltd.

*Powell, Cedric John, B.Sc., Research Student, University of Western Australia.

*Pullum, Geoffrey George, B.Sc., Graduate Apprentice, Handley Page Ltd., London.

*Pyle, Cynthia Lucy, B.Sc., Student, Marconi's College, Marconi's Wireless Telegraph Co. Ltd., Chelmsford, Essex.

*Pyle, John Raymond, B.Sc., Research Engineer, Marconi's Wireless Telegraph Co. Ltd., Chelmsford, Essex.

Rawlins, Timothy George Richard, B.Sc., Graduate Teaching Assistant, University of Minnesota, U.S.A.

*Rees, John Alan, B.Sc., Research Student, University College of Swansea.

Riddoch, Alexander, B.Sc., Research Student, University of Liverpool.

Selwood, Alan, B.Sc., Ph.D., Technician, Bristol Aircraft Co. Ltd., Bristol.

Staines, Alan Edward Cook, B.Sc., Geophysicist, British Petroleum Co. Ltd.,

Sumpton, Jean, B.Sc., Research Physicist, Marconi's Wireless Telegraph Co. Ltd., Chelmsford, Essex.

Swainston, Peter, B.Sc.Tech., Research Physicist, Metropolitan Vickers Electrical Co. Ltd., Manchester.

*Teh Hock Heng, B.Sc., University of Malaya.

Thomas, Benjamin, B.Sc., Research Student, University of Hull.

*Tweedie, James, A.R.T.C., Research Student, University of Sheffield.

Underwood, Gerald, B.Sc., Research Chemist, United Coke and Chemicals Co. Ltd., Sheffield.

Varley, Bruce Clifford, B.Sc., Research Engineer, E.M.I. Electronics Ltd., Feltham, Middlesex.

Varshni, Yatendra Pal, M.Sc., D.Phil., Lecturer, University of Allahabad.

Wells, Michael, B.A., Research Student, Cavendish Laboratory, Cambridge.

Wesley, John Dean, B.Sc., Assistant Lecturer, College of Technology and Commerce, Leicester.

Weston, Peter, B.Sc., Junior Development Engineer, Metropolitan-Vickers Electrical Co. Ltd., Manchester.

Wright, Derek Arthur Yardley, M.A., Senior Physics Master, Wycliffe College, Stonehouse, Glos.

66 Students and 5 Subscribers were also admitted.

The Institute's Journals

PRINCIPAL CONTENTS OF THE MAY, 1957, ISSUES

Journal of Scientific Instruments: Volume 34, No. 5

ORIGINAL CONTRIBUTIONS

A high speed electronic analogue field mapper. By R. B. Burtt and J. Willis (*Electrical Engineering Department, Manchester College of Science and Technology*).

The paper describes an experimental high speed field mapper that was built to demonstrate the feasibility of a purely electronic mapping technique. A complete field is mapped in a twenty-fifth of a second and continuous repetition gives the effect of a moving picture. An elementary phosphor potential stabilization theory is discussed, some of the conclusions of which were verified by experiment. The construction of the mapper is briefly described and some of the field maps are reproduced.

An improved automatic fraction collector. By G. F. H. Box and R. B. Bradbury (*Division of Industrial Chemistry, Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia*).

A fraction collector for chromatography is described which incorporates a new type of liquid dispenser, photo-electrically operated, and capable of delivering predetermined, fixed volumes despite variations in rate of outflow from columns, and changes in density of the liquid.

An ultra-microtome. By A. L. Sims and T. S. Leeson (*University College, Cardiff*).

The instrument is so designed that it can be made in a laboratory workshop where a lathe and a milling or shaping machine are available. The body of the machine is made of a metal with very small coefficient of expansion and carries both the knife and the specimen-holder. The coefficient of expansion of the latter is six and a half times that of the body of the machine and the specimen is moved over the knife by heating this holder. A clear visual field is provided for the operator to cut sections under a binocular microscope. Provision is made for easy handling of the cut sections. To avoid vibration while cutting, the specimen holder is rotated magnetically. Cutting is fully automatic and sections of 1/40 μ (250 Å) can readily be obtained.

A steady state method for the rapid measurement of the thermal conductivity of rocks. By A. Beck, A.Inst.P. (*Australian National University, Canberra, Australia*).

The principle of constant temperature difference is used in a divided bar type of apparatus with which a measurement of the thermal resistance of a specimen

can be completed within twenty minutes. A thick guard ring is used. The diameter of the specimens is made the same as the external diameter of the guard ring, and irregularities in disks, which would cause appreciable errors in a more conventional apparatus, can be tolerated and an accuracy of ± 1% for a single measurement still be obtained.

The a.c. properties of resistors and potential dividers at power and audio frequencies, and their measurement. By G. H. Rayner and L. H. Ford (*National Physical Laboratory, Teddington, Middlesex*).

The alternating-current properties of resistors are briefly discussed, and the time constant and equivalent series inductance and shunt capacitance are defined. The reasons for the variations with frequency are outlined. The determination of the properties is based on standard resistors with windings of simple geometry, for which the inductance and capacitance are calculable. The paper describes methods for comparing such standards with ordinary resistors, for values ranging from a small fraction of an ohm up to about a megohm ; particular attention is given to potential dividers of the Kelvin-Varley type, which have great utility in these measurements. The choice of method depends upon the value of the resistor and, for low values (less than, say, 10 Ω), whether the resistor is a two- or four-terminal one.

A photoelectric particle counter for use in the sieve range. By T. Beirne and J. M. Hutcheon (*Atomic Energy Research Establishment, Harwell, Berkshire*).

A photoelectric particle counter has been designed for the rapid measurement of the number of particles per gram in sieved fractions of opaque powders. The instrument can also be used for the determination of the size distribution of a powder in the sieve range in terms of numbers of particles.

A synthesizer for triangular wave functions. By Prof. Dan McLachlan, Jr. (*Stanford Research Institute, Menlo Park, California, U.S.A.*).

This paper describes an optical analogue computer for summing the Fourier series necessary in computing electron densities of crystals from X-ray data. Aside from its cheapness and ease of handling, its main feature is that the patterns characteristic of the Bragg-Huggins masks are synthesized in the machine by turning a knob which turns in opposite directions two drums upon which are mounted sheets of banded transparent film. Since the projected patterns or fringes are very close to the photographic recording paper, the light scattering is slight.

Obliquity effects in interference microscopes. By C. F. Bruce, F.Inst.P., and B. S. Thornton, A.Inst.P. (*Division of Metrology, National Standards Laboratory, Chippendale, New South Wales, Australia*).

A theoretical analysis is made of the influence of oblique rays on the fringes produced with interference microscopes. The convergency of the light, which is determined by the numerical aperture of the objective, results in the fringes being displaced from the position for ideally collimated light at normal incidence.

The analysis accounts fairly well for some recent measurements of step heights with microscopes of different numerical apertures by Tolman and Wood. The correction due to obliquity is of the order of 10% and over a limited range of step heights, a simple correction rule of $\alpha^2/4$ per unit is satisfactory to about 2% where $\alpha = \sin^{-1}(n.a.)$. The more rigorous formula shows a non-linear relation between obliquity-correction and step-height.

A fast kicksorter channel. By R. D. Amado and R. Wilson (*Clarendon Laboratory, Oxford*).

A single channel kicksorter is described which responds to pulses as short as 10^{-8} s with a dead time of 10^{-7} s.

LABORATORY AND WORKSHOP NOTES

NOTES AND NEWS

NEW INSTRUMENTS, MATERIALS AND TOOLS

MANUFACTURERS' PUBLICATIONS

NOTES AND COMMENTS

British Journal of Applied Physics: Volume 8, No. 5

SPECIAL ARTICLE

The effect of radiation damage on the electronic properties of solids. By E. W. J. Mitchell, A.Inst.P. (*Physics Research Laboratory, University of Reading*).

An outline is given of the way in which the concentration of defects introduced by irradiation may be estimated. The topics which are discussed are the effects of irradiation on the electron mobility in metals, the carrier concentration in germanium and the optical absorption in quartz and diamond. The

emphasis in the discussion of results is on their contribution to the study of defects in solids.

Original contributions

The light output of some phosphors excited with electrons of high current density. By P. A. Einstein (*Associated Electrical Industries Ltd., Aldermaston*).

The behaviour of phosphors at high current densities and at 50 kV has been examined using a pulse technique. For a number of phosphors, the onset of saturation occurs at a high value of current density (in the region of 10^{-1} A/cm^2).

Significant phosphor heating was avoided by use of single pulses of short duration, and did not become important up to current densities of 1 A/cm^2. The rise and decay time constants (though the processes are not exponential) in general increase with current density as has also been reported by other workers for lower current densities. Empirical laws relating time constants to current density have been established.

Dynamic shear properties of some rubber-like materials. By W. P. Fletcher, F.Inst.P., and A. N. Gent, A.Inst.P. (*The British Rubber Producers Research Association, Welwyn Garden City, Herts*).

Measurements are described of the dynamic shear properties of a number of representative rubber-like materials, both vulcanized and unvulcanized, over a wide range of frequencies and temperatures. The major part of the transition from a rubber-like to a glass-like state has been investigated. Reduced values for the real component of the complex shear modulus and the ratio of the imaginary to the real part are presented, enabling the behaviour of the materials studied to be evaluated for other frequency and temperature conditions.

Secondary electron emission from barium dispenser cathodes. By I. Brodie, A.Inst.P., and R. O. Jenkins, F.Inst.P. (*Research Laboratories, The General Electric Company Limited, Wembley, England*).

Measurements of the total secondary electron emission coefficient under electron bombardment δ have been made at room temperature on "L" cathodes and porous tungsten cathodes impregnated with barium calcium aluminates. For "L" cathodes δ decreases with increasing porosity due to the increased surface roughness but δ is always above that for clean tungsten, due to the activation of the surface by adsorbed layers. For the impregnated cathode, δ increases with increasing porosity due to the larger contribution from the impregnant in the pore ends which has a larger value of δ than the surrounding activated tungsten. δ for the impregnated cathode is above that for the "L" cathode and comparable with that for bulk barium oxide. Decay of δ under electron bombardment is observed in the case of the impregnated cathode but the initial value can always be recovered by heating.

Vacuum-deposited films of nickel-chromium alloy. By R. H. Alderson and F. Ashworth (*Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17*).

The preparation and properties of stable films of vacuum-deposited nickel-chromium alloy are described. Properties discussed include the film-alloy composition, the relationship between film thickness and resistance (Ω/square), the temperature coefficient of resistance, grain size in the film (electron micrographs), mechanical failure of stressed films, optical transmission as a function of film thickness, fundamental noise and electrical breakdown under low- and high-frequency conditions. Graphs summarize the data and micrographs illustrate grain growth, breakdown due to stresses in the film and electrical breakdown in microwave attenuators.

The conductance of a column of vapour for gases at low pressures. By D. S. Stark, A.Inst.P. (*Services Electronics Research Laboratory, Baldock, Herts*).

Vacuum systems often contain stationary columns of vapour. A general expression is derived for the conductance of such a column for gases at low pressures.

A rough experiment using columns of mercury vapour yielded values for the conductance for air and hydrogen which were of the same order of magnitude as the values predicted from the expression given.

It is shown that the conductance of the vapour can be less than that of the pipe which contains it. This becomes increasingly probable as the pipe diameter and the vapour pressure are increased.

Notes and news

New books

Notes and comments

UNITED KINGDOM
ATOMIC ENERGY AUTHORITY

SENIOR HEALTH PHYSICIST

Applications are invited for a senior appointment in the Technical Section of the Operations Branch at the Industrial Group Headquarters, Risley, Warrington, Lancs.

The Technical Section co-ordinates the technical activities of a number of large Works at which reactors, chemical, metallurgical and diffusion plants are in operation. It includes a Health Physics team which is engaged on applied aspects of health and safety, including criticality, and which deals with current and longer term problems affecting the Works.

The duties of the post include supervision of the Health Physics team at Headquarters, co-ordination of the activities of the Health Physics sections at the Works and of experimental work in this field, and liaison with the Safety and other Branches.

Applicants should be between 35 and 45 years of age and must possess an Honours Degree in Physics, or hold equivalent qualifications. Familiarity with radiation work is desirable but not essential, providing applicants can produce evidence of suitable alternative industrial experience.

Salary will be assessed within the range £2,000 to £2,500 p.a.

A contributory Pension Scheme is in operation.

An authority house for renting by the successful candidate, if married, may be available in due course, or alternatively, substantial assistance may be given towards legal expenses incurred in private purchase.

Application forms may be obtained from the Chief Recruitment Officer, U.K.A.E.A., I.G. Hq., Risley, Warrington, Lancs. (Ref. number 1862.)

Closing date, May 20, 1957.

BRITISH THOMSON-HOUSTON

The British Thomson-Houston Co. Ltd., has a vacancy in the semiconductor group of its Research Laboratory at Rugby for a mathematical physicist. The work is concerned with the analysis of data obtained from the varied experiments on semiconductor materials and the devices made from them, and also the application of theoretical physics to the search for new semiconducting materials and devices.

The position is pensionable and offers excellent prospects.

Applicants are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Rugby, stating age, qualifications and experience, and quoting reference W1.

MECHANICAL or ELECTRICAL ENGINEER or PHYSICIST required at Royal Aircraft Establishment, Farnborough, Hants, to work on design and development of precision test equipment for gyroscopes and accelerometer including development of precision centrifuge. Candidates should have 1st or 2nd class honours degree or equivalent in mechanical/electrical engineering or physics. Appointment as Scientific Officer (min. age 21). Salary within range £565–£995 (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting C168/7A. Closing date May 24, 1957.

MATHEMATICIAN or STATISTICIAN required for the analysis of production and experimental data obtained on steel-making furnaces. The duties include the development of advanced techniques for the collection and study of data, and experience in this field and in instrumentation of steel industry processes would be useful.

Applicants should be preferably of University degree or equivalent standard with industrial experience but consideration will be given to those of lower academic attainment with adequate industrial or research experience. The successful applicant will operate as a member of the Central Research Laboratories but the duties will necessitate frequent visits to the production sections of the Company.

The commencing salary will depend on the age, qualifications and experience of the applicant, but will be normally in the range £650 – £1,100. The position will be progressive and pensionable. Staff canteen and transport available.

Address enquiries in confidence to the Director of Research, Central Research Laboratories, Richard Thomas & Baldwins Ltd., The Firs, Whitchurch, Aylesbury, Bucks.

AUCKLAND UNIVERSITY COLLEGE
(UNIVERSITY OF NEW ZEALAND)

The College Council invites applications for two vacant Senior Lectureships in Physics. The department is interested in various research fields, including angular correlation of nuclear radiations, polarized nuclear reactions ; ion optics ; time-of-flight of neutrons. Preference would be given, other things being equal, to candidates with theoretical or experimental knowledge of any of the above fields ; or similar fields, combined with special qualifications as a lecturer in either (*a*) nuclear physics ; or (*b*) advanced electricity and magnetism.

The salary scale for a Senior Lecturer is £1,275 – £1,575 per annum, by three annual increments. Commencing salary within this scale for the two physics posts will be fixed according to qualifications and experience. An allowance is made towards travelling expenses.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in New Zealand and London, is May 31, 1957.

THE BRITISH IRON AND STEEL RESEARCH ASSOCIATION

REQUIRES A

GRADUATE PHYSICIST

for design and development work in the field of instrumentation for industry and research. Capacity for original thinking is as important as specialist experience. Good knowledge of applied physics essential, allied to an aptitude for experimental work. Location of work London, S.W.11. Starting salary up to £900 p.a. according to age, qualifications and experience. Post is superannuated under the F.S.S.U. Written applications only, quoting P.Y.1. to the Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

AIR MINISTRY requires Senior Scientific Officers and Scientific Officers for work in Scientific Adviser's Organization, on operational research including tactics, technical development and logistics. 1st or 2nd class honours degree in mathematics, science or engineering, or equivalent. Salary (London) £1,135 – £1,345 (S.S.O. men) and £605 – £1,055 (S.O. men). Provincial rates and rates for women slightly lower. Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A33/7A.

PHYSICIST or ELECTRICAL ENGINEER required by Ministry of Supply at R.A.E., Bedford, for design of precision electrical and electronic instruments for use in wind tunnel operation and for measurement of physical quantities in wind tunnels. 1st or 2nd class honours degree or equivalent in physics or electrical engineering, with at least three years' postgraduate research experience. Appointment as Senior Scientific Officer (min. age 26) with salary in range £1,075 – £1,265 (superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A117/7A. Closing date June 24, 1957.

THE ELECTRICAL RESEARCH ASSOCIATION invites graduates or prospective graduates in physics or engineering to apply for appointments at the new Leatherhead Laboratory. There are opportunities in the following fields :

(1) Thermal behaviour of buildings.
(2) Storage of electrical energy as heat.
(3) Thermodynamic problems in new applications.
(4) Properties and behaviour of insulating materials.
(5) Performance of high voltage insulation in service.
(6) Light current engineering.
(7) Use of electricity in explosive atmospheres.

Minimum qualification 2nd class honours degree or equivalent. Initial salaries will be assessed within the range £625 – £900 p.a. depending on qualifications and experience. Eligible applicants will be admitted into superannuation under F.S.S.U. on confirmation of appointment.

Applications should be addressed to : Personnel Officer, Electrical Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey.

RESEARCH OFFICERS are required by the Heating and Ventilating Research Council at their Leatherhead Laboratories, Surrey, for investigation of basic problems in the field of heating and ventilation. This Council receives support from the Department of Scientific and Industrial Research. Applicants should be physicists or engineers of graduate or equivalent standard and should be familiar with experimental methods and measuring techniques. Previous experience in heating and ventilation is not essential but some knowledge of either heat transfer, fluid flow, automatic control or instrumentation would be an advantage. Excellent opportunities for advancement. Superannuation. Five-day week. First rate facilities. Salary to be negotiated. Write giving full details to : Secretary, Heating and Ventilating Research Council, c/o B.C.U.R.A., Laboratories, Randalls Road, Leatherhead, Surrey.

UNIVERSITY PRESS, CAMBRIDGE, has a vacancy for a Sub-Editor for preparing MSS. for press. Good knowledge of mathematics and physics needed, preferably to degree standard. Starting salary (inclusive) about £650. Apply to The Printer, University Press, Cambridge.

UNIVERSITY OF BIRMINGHAM

Applications are invited for a Physicist to participate in interesting research programme into the use of electrical analogies for the solution of problems in mathematical physics. A good honours degree is essential and preference will be given to candidates who have had some research or practical experience. Salary £650 – £1,200 per annum, the initial salary being dependent upon the qualifications and experience of the person appointed. A candidate would be expected to show ability in research, and to have had two or three years' postgraduate research experience, to qualify for a salary at the upper end of the range. The appointment is to commence on July 1, 1957, or as soon thereafter as possible.

Applications should be sent not later than May 31, 1957, to Professor S. C. Redshaw, Dean of the Faculty of Science, The University, Edgbaston, Birmingham, 15.

SUNDERLAND EDUCATION COMMITTEE

THE TECHNICAL COLLEGE

Principal : D. A. Wrangham, M.Sc.(Lond.), Sen.Wh.Sch., D.I.C., A.C.G.I., M.I.Mech.E.

Applications are invited for the post of Assistant Grade "B" in the Physics Department.

Candidates must be well qualified in Physics and a qualification or experience in teaching would be a recommendation. The salary will be in accordance with the Burnham Scale for Assistants (Grade B) £650 × £25 – £1,025 plus allowance for training, graduate qualifications and experience. Further particulars and forms of application may be obtained from the Registrar, The Technical College, Sunderland, Co. Durham. Applications should reach the undersigned as soon as possible after the appearance of this advertisement.

Canvassing will be a disqualification.

W. Thompson
Director of Education.

Education Offices,
15 John Street,
Sunderland.

ATOMIC ENERGY RESEARCH ESTABLISHMENT HARWELL

METALLURGY DIVISION

requires an honours physics graduate for investigation by electron diffraction into problems associated with the surface structure of materials to be used in the Nuclear Power Programme. Some experience of this, or vacuum work, desirable ; subsidiary problems requiring knowledge of electron microscopy may also arise. There will be opportunity for publication of results of research.

Salary : £1,155 – £1,355 (Senior Scientific Officer)
or £615 – £1,065 (Scientific Officer)

Send postcard for full details and an application form, which must be returned by May 22 to the Group Recruitment Officer, A.E.R.E., Harwell, Didcot, Berks, quoting 781/110.

INDUSTRIAL ELECTRONICS

A Senior Engineer is required to undertake work on a variety of projects in the industrial electronics field. The applicant should have an honours degree in physics or electrical engineering and be capable of leading a team. Salary will be in accordance with age, qualifications and experience. London area. All applications will be treated as confidential and should be sent to The Employment Manager, The Plessey Co. Ltd., Ilford, Essex.

Appointments Vacant

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

PLESSEY NUCLEONICS LTD., have a vacancy for a Physicist to carry out original work on radiation detection devices. Applicants should possess a degree in physics and could have an interest in mathematical physics. Alternatively, an interest in the application of electronics to reactor instrumentation and control or in the field of reactor physics would be desirable. A generous salary will be offered, based upon qualifications and previous experience. Please write in confidence giving full particulars to The Chief Engineer, Plessey Nucleonics Ltd., Weedon Road, Northampton.

UNIVERSITY OF CAPE TOWN

Applications are invited for a vacant Lectureship in Physics. The salary scale is £850 × £50 – £1,200 per annum. There is also a temporary cost of living allowance for a married man (at present £234 per annum).

Applications (with copies of testimonials) should state age, qualifications, experience and research work completed or in progress and give the names of two referees whom the University may consult. Two copies of the application and testimonials should reach the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1 (from whom memoranda giving the general conditions of appointment and further information about the work of the department of physics should be obtained) not later than July 8, 1957. An additional copy should be sent direct by airmail to the Registrar, University of Cape Town, Private Bag, Rondebosch, Cape Town, South Africa, by the same date.

The University reserves the right to appoint a person other than one of the applicants or to make no appointment.

THE BRITISH THOMSON-HOUSTON CO. LTD.

The British Thomson-Houston Co. Ltd., has vacancies for physicists in a group carrying out investigations into the properties of semiconducting materials. The work will be mainly concerned with the physical properties of rectifiers and associated devices, and offers wide experience in both fundamental and applied research in a rapidly expanding field.

Applicants are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Rugby, stating age, qualifications and experience and quote reference SJ.

UNIVERSITY OF ST. ANDREWS

QUEEN'S COLLEGE, DUNDEE

LECTURESHIPS IN PHYSICS

The University Court of the University of St. Andrews invites applications for two Lectureships in Physics in Queen's College, Dundee, both of which will take effect from October 1, 1957. The present salary scale for each post is £650 × £50 – £1,350, with efficiency bar at £1,000, but the scale is under review and placing will be on the newly revised scale, according to qualifications and experience. F.S.S.U. and family allowance benefits ; a grant towards removal expenses will be made. Six copies of the application, which should contain the names of three referees should be lodged with the undernoted, not later than May 31.

Patrick Cumming,
Joint Clerk to the University Court.

PRINCIPAL/SENIOR SCIENTIFIC OFFICER required by the Atomic Weapons Research Establishment, Aldermaston, Berks, to lead a small team carrying out original research in electronics on problems arising in connection with nuclear physics investigation. First or second class honours degree (physics or electrical engineering) required together with experience of conducting independent research in suitable aspects of electronics. Pulse and high speed techniques are particularly relevant.

Salary : Principal Scientific Officer—£1,390 – £1,980 per annum (male) ; Senior Scientific Officer—£1,155 – £1,355 per annum (male).

Contributory superannuation scheme. A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance.

Postcards for application forms to the Senior Recruitment Officer at above address. Please quote ref. 1498/110.

MATHEMATICAL PHYSICISTS OR MATHEMATICIANS

required by

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT, ALDERMASTON, BERKS, in the grades of Principal/Senior/Scientific Officer to work in one of the following fields : astro, atomic or reactor physics, atmopheric diffusion, statistics or stochastic theory, statistical, fluid, solid or general applied mechanics, numerical analysis involving use of large digital computers.

Qualifications and experience : Applicants should have a first or second class honours degree in mathematics or mathematical physics, and preferably some years' postgraduate research in one of the above or allied fields.

Salary : P.S.O. £1,390 – £1,980 p.a. (male)
S.S.O. £1,155 – £1,355 p.a. (male)
S.O. to be assessed according to age, qualifications and experience within the scale £610 – £1,065 p.a. (male).

Contributory superannuation scheme.

A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance. Postcards for application forms to Senior Recruitment Officer at the above address.

Please quote ref. A/1320.

SENIOR SCIENTIFIC OFFICERS

required by

THE ATOMIC WEAPONS RESEARCH ESTABLISHMENT, ALDERMASTON, BERKS, to carry out fundamental studies in the field of fast neutron physics. First or second class honours degree (physics) required ; postgraduate experience in nuclear physics essential.
Salary : £1,155 – £1,355 per annum (male).
Contributory superannuation scheme. A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance.
Postcards for application forms to Senior Recruitment Officer at the above address. Please quote reference 1501/110.

RADIOLOGICAL PROTECTION SERVICE (Ministry of Health and Medical Research Council), Clifton Avenue, Belmont, Sutton, Surrey, require :

1. Physicist, with bias towards theoretical work, for work on scattering, absorption, and measurement of ionizing radiations. Opportunities for experimental research. Experience and interest in mathematical physics necessary.
2. Radiochemist for development techniques to determine radioactive isotopes in liquid, solid, and gaseous media, e.g. excreta, dust, samples from air, food. Experience in radiochemical work preferred.
3. Physicist to develop equipment for measuring ionizing radiations and radioisotopes. Experience or interest in electronics preferred.
4. Physicist to assist with radiation-monitoring services for external ionizing radiations and for radiation surveys of specific groups of workers.
5. Physicist to assist in developing more accurate techniques for assessing amounts of radiation received by workers.
6. Physicist to assist in study of miscellaneous radiation protection problems, e.g. X-rays from television sets.

Applicants should hold good honours degree or equivalents (in physics for posts 1, 3, 4, 5 and 6—in chemistry for post 2). Salary (according to age and experience) at point on scales £715 (× £35 – £750 × £50 – £900) (posts 1 and 2) and £500 (× £35 – £535 × £30 – £565 × £25 – £690) (posts 3 to 6), scales likely to be improved later this year. Superannuation provision—after one year for newly qualified graduates ; immediately for others. Child allowances. Applications (full details academic and subsequent careers, and names of two professional referees) to Director of Service, from whom further details may be obtained.

BEN JOHNSON & CO. LTD. requires a Technical Assistant of superior education and good background, with a sound grasp of chemistry and physics. Acquaintance with letterpress, lithography and, if possible, gravure is desirable, though this last is not vital. The successful applicant would be trained in the latest printing techniques and would be required, amongst his other duties, to visit Trade Exhibitions, leading print houses here and abroad, and manufacturers of printing machinery, with a view to improving his ability to make suggestions on the latest developments in the industry. Commencing salary £750 to £800 p.a. Write giving age and full details of education, personal background and practical experience to the Secretary, Boroughbridge Road, York.

ELECTRONIC RESEARCH, DEVELOPMENT AND DESIGN

Hilger & Watts Ltd. extend a cordial invitation to join their Research Division to graduates in Physics or Electrical Engineering anxious to work in the fields of instrumentation, automatic control, microwave development and data reduction and on the wide and up-to-date problems arising in these fields. These vacancies are due to the Company's expanding electronics development programme. Every assistance and encouragements will be given, but only young men of enthusiasm, initiative and drive will be considered. The Company has vacancies also for young men with Higher National Certificate or equivalent who would be interested in testing and servicing instruments and helping generally in the solution of problems of design. All the posts are permanent and pensionable and letters giving full details of qualification and experience should be addressed in the first instance to The Chief Personnel Manager, Hilger & Watts Ltd., 98 St. Pancras Way, Camden Road, N.W.1.

BRITISH CELANESE LTD., invites applications from Graduate Physicists up to 30 years of age for research appointments at their factory at Spondon, near Derby. The work will be particularly concerned with the application of the methods of physics to the solution of textile problems and will afford a valuable introduction to a career in the textile industry. Salary in accordance with age and qualification ; pension scheme. Please reply to the Personnel Manager, British Celanese Ltd., Celanese House, Hanover Square, London, W.1, quoting Ref. 1231.

NORTHERN POLYTECHNIC

Session 1957-58

Advanced Courses in

Electronics and Microwave Physics

Electrical Discharges in Gases

Solid State Physics

Suitably qualified students can proceed to the M.Sc. degree of the University of London. Session commences September 23, 1957.
Also short lecture courses on :

Introduction to Electronics and Microwave Physics—commencing October 2, 1957.

(This is designed for graduates requiring basic electronics for industrial applications).

Transmission Lines—commencing October 2, 1957.

Mathematics of Circuit Analysis—commencing October 2, 1957.

Wave-Guides—commencing November 6, 1957.

Amplifiers—commencing November 6, 1957.

Enquiries should be addressed to :

Head of Department of Physics,
Northern Polytechnic, Holloway,
London, N.7.
(Telephone : NORth 1686)

UNIVERSITY OF SOUTHAMPTON

Applications are invited for the post of Lecturer or Assistant Lecturer in the Department of Physics. Salary scales : Lecturer £900 × £50 – £1,350 × £75 – £1,650 ; Assistant Lecturer £700 × £50 – £850. Preference will be given to candidates prepared to lecture in electronics or nucleonics. Duties to commence on October 1, 1957. Further particulars should be obtained from the Secretary and Registrar, to whom applications (7 copies) should be sent not later than June 25, 1957.

NORTHERN POLYTECHNIC, HOLLOWAY, LONDON, N.7.

The Governing Body invite immediate applications for appointment as full-time Assistant Lecturer in Physics to commence in September, 1957. Facilities available for research. Salary scale £650 × £25 – £1,025, together with allowances in accordance with Burnham Award. Commencing salary according to age, qualifications and experience. Particulars and form of application from the Clerk to the Governors.

ROYAL TECHNICAL COLLEGE, SALFORD

Acting Principal : J. F. Yates, B.Sc., M.Sc., M.I.E.E.

The Governors of the College, which has now been designated a College of Advanced Technology, invite applications for the post of Assistant Lecturer, Grade B, in Physics. Candidates should preferably have had some teaching, industrial and/or research experience. The salary will be in accordance with the Burnham Technical Scale for Grade B Assistants £650 – £1,025 (men) ; £580 – £820 + 3/7ths differential (women) ; plus graduate, training and approved industrial experience allowances. The successful candidate will be required to commence duty on September 1, 1957. For further particulars and forms of application please send a stamped addressed envelope to the Acting Principal, Royal Technical College, Salford, 5. Applications should be returned as soon as possible.

R. Ribblesdale Thornton,
Clerk to the Governors.

UNIVERSITY OF WESTERN AUSTRALIA

Applications are invited for the posts of Senior Lecturer in Physics and Lecturer in Physics.

Applicants for the Lectureship should hold an honours degree and should have undertaken postgraduate research in experimental or theoretical Physics. Applicants for the Senior Lectureship should hold a higher degree.

The salary range is at present £A1,850–£A2,150 per annum for Senior Lecturers and £A1,250 — £A1,750 for Lecturers, plus cost-of-living allowance (at present £A36 p.a.). The commencing salary will in each case be determined on the basis of the qualifications and experience of the appointee. An allowance is made towards travelling expenses. Housing assistance available.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in Australia and London, is June 30, 1957.

MIDDLESEX COUNTY COUNCIL
Education Committee
Brunel College of Technology
Acton, W.3.

This college is to open in new buildings in September, 1957, and will take over the advanced work of Acton Technical College.

Applications are invited for the Headships of the following departments, each of which will initially be a Grade III Department :

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MATHEMATICS

Candidates should be highly qualified and have suitable industrial and/or research experience, and preferably some full-time and/or part-time University or Technical College lecturing experience. There is an opportunity to build up new departments and to develop Sandwich courses for the Diploma in Technology, Postgraduate Technological Courses and Research. Salary in accordance with the Burnham (Technical) Report, 1956, i.e. £1,600 × £50–£1,750 plus London allowance.

Further particulars and application form (stamped addressed foolscap envelope) from the Clerk to the Governing Body, Middlesex County Council, Education Department, 10 Great George Street, Westminster, S.W.1, to whom completed forms should be returned by June 21, 1957.

C. E. Gurr, M.Sc., Ph.D.,
Secretary to the Education Committee.

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